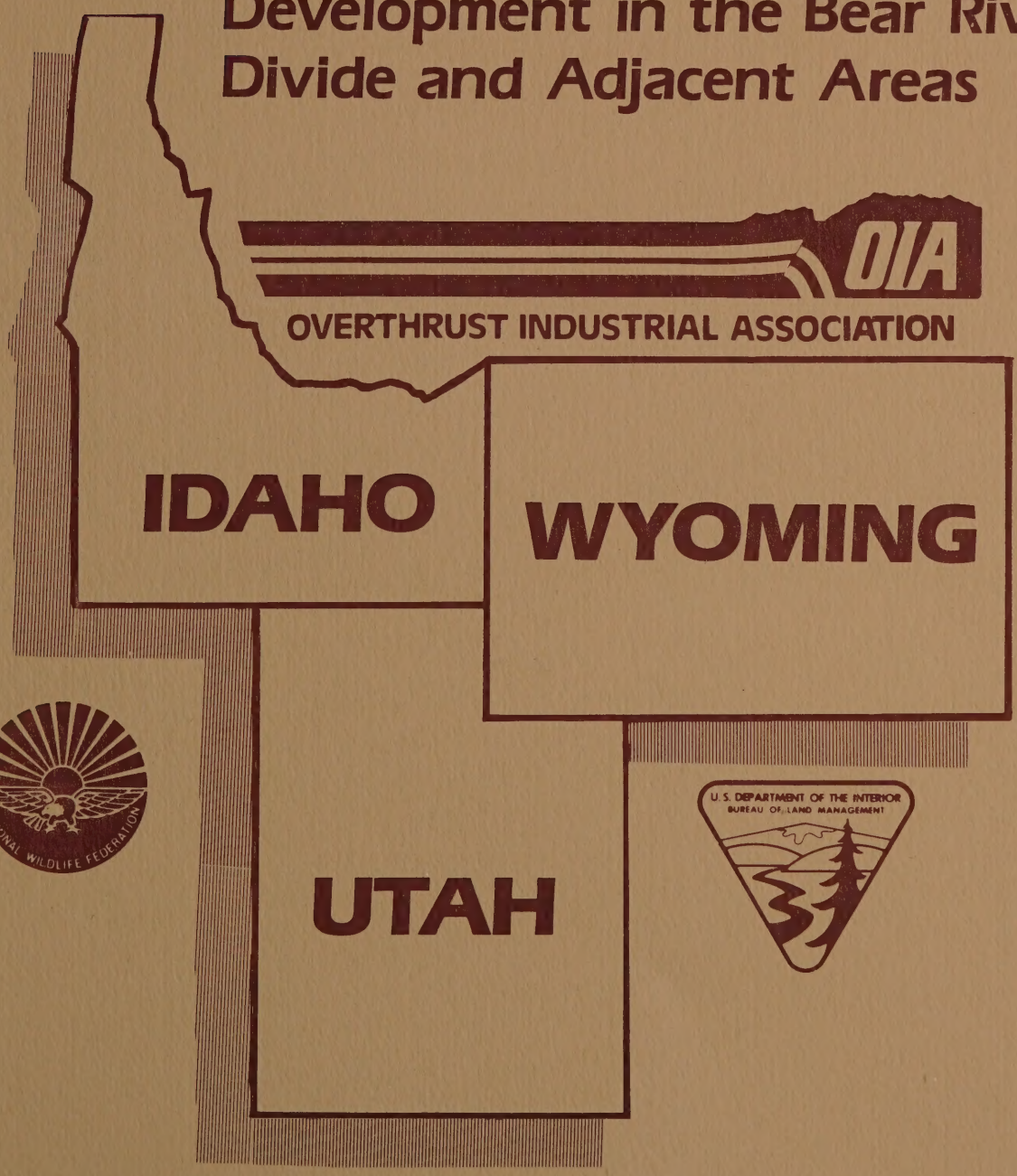
BLM LIBRARY
88013276

Cooperative Wildlife Program

A Reclamation Manual:

Suggested Practices for Land Disturbed by Oil and Gas Development in the Bear River Divide and Adjacent Areas



ID 88013276

#16620393

BLM Library
D-553A, Building 50
Denver Federal Center
P. O. Box 25047
Denver, CO 80225-0047

QL
84.22
.R6
C66
1985
V.1

A RECLAMATION MANUAL:

SUGGESTED PRACTICES FOR LANDS DISTURBED BY OIL AND GAS DEVELOPMENT IN THE BEAR RIVER DIVIDE AND ADJACENT AREAS

July, 1985

Prepared By:

NPI Reclamation Services
University Research Park
417 Wakara Way
Salt Lake City, UT 84108
801-582-0144

Printed Courtesy of:

Chevron U.S.A., Inc.
P.O. Box 599
Denver, CO 80201

BLM Library
D-555A, Building 50
Denver Federal Center
P. O. Box 25047
Denver, CO 80225-0047

ACKNOWLEDGEMENTS

This document is one of several developed for the Overthrust Industrial Association's (OIA) Cooperative Wildlife Program. It was prepared by NPI Reclamation Services with primary authorship by Dennis Hansen, Kent Ostler, and Kevin Allred.

The section on snow control with snow fences was supplied courtesy of Ronald D. Tabler, Rocky Mountain Forest and Range Experiment Station, Laramie, WY.

Members of the Project Coordinating Committee reviewed the draft report and their comments are included in this document.

This document is printed courtesy of Chevron U.S.A., Inc. Additional copies are available on request:

Chevron U.S.A., Inc.
Attn: Regulatory Affairs
P.O. Box 599
Denver, CO 80201

TABLE OF CONTENTS

Section	Page Number
INTRODUCTION	1
Application and Limitations of the Manual	2
SELECTION OF RECLAMATION PRACTICES	3
Major Land Use Objectives	3
Wildlife Habitat	4
Erosion Control	4
The Reclamation Practices Matrix	7
Vegetation Types	7
Soil Types	9
Slopes	9
Priority Ratings	9
RECLAMATION PRACTICES	11
Site Selection and Evaluation	11
Site Clearing and Preparation	13
Water Management	16
Seedbed Preparation	37
Seeding	40
Planting	48
Fertilizing	54
Mulching	55
Monitoring and Maintenance	59
SPECIAL PROBLEMS AND CONSIDERATIONS	60
Grazing	60
Weed Control	61
Soil Amendments	63
Spills and Reserve Pit Rehabilitation	64
Animal Damage	66
Management of Blowing Snow	67
Riparian Zones and Wetlands	71
ECONOMIC CONSIDERATIONS	75
CONTRACT SPECIFICATIONS	80
SUMMARY	83
LITERATURE CITED	85

APPENDICES

A. Common and Scientific Name of Species
B. Snow Control with Road Design and Snow Fences

LIST OF TABLES

		PAGE
Table 1.	Reclamation practices matrix	8
Table 2.	Criteria to establish suitability of topsoil or topsoil substitute	15
Table 3.	Recommended species for seeding in the dry vegetation types	42
Table 4.	Recommended species for seeding in the intermediate vegetation types	43
Table 5.	Recommended species for seeding in the moist vegetation types	44
Table 6.	Ranges of costs and major factors influencing cost often incurred for common revegetation practices	78

LIST OF FIGURES

		PAGE
Figure 1.	Comparisons of different measures of slope gradients	10
Figure 2.	Composite drawing showing several water management techniques utilized on a drill site	18
Figure 3.	Example of construction specifications for intercept ditches	21
Figure 4.	Example of construction specifications for contour furrows	23
Figure 5.	Example of construction specifications for terraces	25
Figure 6.	Example of construction specifications for waterbars	27
Figure 7.	Example of contour ripping	28
Figure 8.	Example of construction specifications for pipe slope drain	30
Figure 9.	Example of construction specifications for straw bale dike	31
Figure 10.	Schematic of a drainage dip designed to transfer water across a road without slowing traffic appreciably	33
Figure 11.	Diagram showing proper installation of culverts	34
Figure 12.	Example of a gabion	36
Figure 13.	Example of slope chaining	39
Figure 14.	Planting technique for steep slopes	53
Figure 15.	Schematic showing proper installation of excelsior mat	57

INTRODUCTION

This report is one of several developed for the Overthrust Industrial Association's (OIA) Cooperative Wildlife Program. It is a manual describing suggested reclamation techniques and practices that have proven effective in controlling soil erosion and for reclamation of wildlife habitat. The term reclamation as used in this report is defined broadly as the process of returning a disturbed site to a condition approximately equal to or better than that prior to disturbance in terms of sustained support of function, physical processes, biological organisms and land uses. Recommendations focus on lands altered by oil and gas development located on the geological formations known as the "Overthrust Belt" and "Bear River Divide." The recommendations described here are suitable for reclamation of sites located in most areas of Uinta and Lincoln Counties in Wyoming, Rich and Summit Counties in Utah, and Bear Lake County in Idaho, although much of the information is also applicable to other adjacent areas with similar climatic and soil conditions.

This manual is primarily based on information contained in two reports, Appendix I and II (OIA 1985), which are provided as a separate document. Appendix I consists of a literature review of applicable reclamation practices and interviews with knowledgeable individuals to determine their concerns and suggestions. It documents success and costs of reclamation techniques tested and used both in the Bear River Divide region and adjacent areas with similar climatic and physical conditions and identifies concerns about reclamation of wildlife habitat that are addressed in this manual. Appendix II contains the results of a field assessment which intentifies the most common land use and reclamation objectives, types and severity of erosion, and reclamation problems occurring in the Bear River Divide and adjacent areas. The reader is referred to these Appendices for detailed technical discussions and additional information.

Preparation of the reclamation manual has focused primarily on four task objectives:

- Recommend reclamation practices that are appropriate for commonly occurring site conditions.
  (Selection of Reclamation Practices)

- Describe selected reclamation practices and how they are to be implemented.
  (Reclamation Practices)

- Describe approaches that can be used to determine which reclamation practices are most cost effective.
  (Economic Considerations)

- Describe specifications for materials and services that can help in preparing bid specifications for selected reclamation practices.
  (Specifications)

The following sections of this manual provide information to help achieve these objectives.

APPLICATIONS AND LIMITATIONS OF THE RECLAMATION MANUAL

The manual focuses predominantly on reclamation techniques and assumes that the reader will supplement this information with personal experience and guidance from private land owners, industry, government land stewards, and concerned public organizations. We have attempted to present materials in a logical and orderly fashion in which information is understandable and consistent with sound environmental and wildlife management principles. However, because of the diverse background of readers who may have a need to use this information, it is anticipated that some concepts may be more easily grasped than others. We encourage readers to contact their colleagues and other knowledgeable individuals to enhance their understanding of the principles and techniques discussed here.

Recommendations for appropriate practices are based on reclamation practices that have been demonstrated to be effective under similar conditions elsewhere. They are also based on the most prevalent site conditions and reclamation problems in the Bear River Divide region, as observed during field observations and from discussions with knowledgeable individuals. These recommendations have been developed specifically for lands altered by oil and gas development activities.

The manual focuses on the most commonly disturbed wildlife habitat areas. Recommendations for these areas are meant to serve as guidelines for developing and implementing reclamation plans. They should not be construed to be the "only" or the "most suitable" techniques for all situations or areas, but should be considered as "basic practices" from which more appropriate or site specific techniques or practices can be developed. It is emphasized that these selected practices are intended to serve as a management framework as opposed to standards and specifications to be adopted as laws or ordinance. There are major disadvantages to precluding innovations to wildlife habitat rehabilitation and erosion control by law or ordinance which allow only selected practices. Furthermore, practices are designed and recommended based on analysis of specific site conditions which may be both diverse and unique. Flexibility and innovation are the keys to successful achievement of wildlife habitat rehabilitation and erosion control. Industry operators, private land owners, and government land-managers are encouraged to develop more effective techniques and practices through experimental procedures and insight gained through reclamation research in the Bear River Divide and adjacent areas.

SELECTION OF RECLAMATION PRACTICES

MAJOR LAND USE OBJECTIVES

It has been said that all great journeys begin with a single step. While this is certainly true, it is also clear that if we intend to reach our destination it is important that the first step be in the right direction. Imagine the confidence you would have in a commerical airline pilot who welcomed you on a flight to Hawaii and informed you that he "kind of knew where Hawaii was located" and that he would "steer in that general direction" and "do his best to get you there." Good intentions are not enough! What is required is a clearly defined destination and delineated course along the way. The direction and course that leads to our desired destination should be foremost in our minds as we begin any reclamation project. In this regard the land use and reclamation objectives provide the guiding force that steers the reclamation efforts toward their desired destination. The land use objective is the broad, overall goal that is desired in the long term. Reclamation objectives might be thought of as short-term goals or steps that are required to direct the reclamation process to the final land use goal. When land use or reclamation objectives are glossed over or ignored, subsequent reclamation efforts may be in vain and lead to undesirable economic, legal, and environmental consequences.

In addition to a clearly defined destination, success in achieving objectives also requires necessary supporting technology along the way. While significant improvements and advances have been made in reclamation techniques during the past two decades, these techniques are merely tools to assist us in reaching our destination, they are not substitutes for the careful planning and skill that must be exerted! Predisturbance planning is essential to potentially successful reclamation. As discussed in Appendix I (OIA 1985), this planning should include such activities as:

- Baseline studies that characterize the predisturbance environment.
- Identification of potential impacts of development on the environment.
- Identification of land use and reclamation objectives for mitigation of the impacts.
- Identification of specific reclamation problems.
- Development of a specific reclamation plan to overcome problems and, thereby, achieve the desired objectives.

The reader is referred to Appendix I for a more detailed explanation of these activities.

For the purposes of this manual it is assumed that much of the baseline information has been collected and that potential adverse impacts have been identified. Additional site specific information may have to be collected during site visits and through coordination with industry personnel responsible for development of the project and with government or private

land owners regulating such development activities. Specific reclamation problems have been addressed in Appendix II (OIA 1985), and the reader is referred to this report for a more detailed description of those findings.

Based on the information that has been developed to date by the Cooperative Wildlife Program and the most commonly occurring site conditions, we have suggested several reclamation practices and described them in such a manner that the reader should be able to develop a specific reclamation plan for a selected site. It is assumed that the land use objectives would be that of reclaiming the area to wildlife habitat and controlling erosion.

Wildlife Habitat

Because wildlife populations are generally limited by habitat availability, disturbed-land reclamation for wildlife generally involves reestablishment of requisite physical and biological features of habitat. Reclamation planning from a wildlife standpoint should strive to design physical and vegetational habitat conditions that complement surrounding undisturbed habitat features in terms of support of important wildlife species. Topographic configuration is the major aspect of physical habitat reconstruction, while plant community diversity considerations are of prime importance in the vegetational aspects of habitat such as food and cover. Disturbed site revegetation programs should strive to establish sufficient diversity within plant communities to provide both presence and proper structural composition of needed plant species and growth forms. Because interplant community diversity is also of major importance to many wildlife species, disturbed sites may be beneficially revegetated to more than a single community type or to a different community type than the surrounding undisturbed area.

The extent and ease with which the reclamation scientist can manipulate the various factors comprising wildife habitat through reclamation will determine the rate of recovery of disturbed lands for support of wildlife. It is important to realize that achievement of reclamation goals on drastically disturbed lands will never be achieved overnight. Rather, the process of reestablishing wildlife habitat should be viewed as an extended process, of which reclamation is merely a beginning and serves to set the process in motion. The long-term nature of this process emphasizes the need for adequate protection of the site from external disturbances and the need for conscientious monitoring and maintenance of the site if wildlife land use goals are to be achieved.

Erosion Control

Because many essential features of wildlife habitat, such as adequate food and vegetative cover, often require several years to develop, it is important that consideration be given to protecting site resources such as soil and watershed features until the vegetative cover is sufficiently established and self-perpetuating to protect the site against further degradation. For this reason, a secondary short-term goal of erosion control should be considered as essential for properly achieving the more long-term goal of wildlife habitat rehabilitation. A brief discussion concerning the causes of soil erosion and its effect on the environment

follows. It is based on a format published by Thronson (1971) for the Environmental Protection Agency as published in the Erosion-Sediment Control Handbook of the Salt Lake County Water Quality & Pollution Control (1981). The discussion has been modified and directed to the Bear River Divide and adjacent areas.

Causes of Accelerated Erosion. The principal influence that land development activities have on the natural erosion process results from the exposure of disturbed soils to precipation and storm-runoff water. Shaping of land for development purposes alters the soil cover in many ways, often detrimentally affecting the drainage, runoff, and stream flow. During development, protective vegetative cover is removed, excavations are made and the removed material stockpiled without cover, slopes are modified by making steep cuts and fills, and the physical properties of the soil are changed.

The energy responsible for erosion is provided by falling rain and flowing runoff water. One inch of precipitation falling on one acre of exposed soil weighs 110 tons. In the higher elevations of the Bear River Divide area, where the average annual rainfall is about 30 inches, approximately 3,300 tons of precipitation fall on each acre of land during the year. In the lower portions of the area, where the average annual rainfall is about 12 inches, the figure would be about 1,320 tons. This falling precipitation and runoff provide the energy required to erode large quantities of soil from areas under development and transport it farther downstream.

If natural vegetation is left upon land being developed, the kinetic energy of the falling rain is dissipated. If it is removed, the bare disturbed soil receives the full force of the energy. Raindrops strike the ground at a velocity of about 19 miles per hour, knocking individual soil particles loose and compacting the exposed soil surface. Runoff increases as the compacted soil becomes less permeable and the soil particles loosened by rain drops are carried down the slopes by overland flow. The impact of rain falling for one to four minutes is known to decrease infiltration to such an extent, even in sandy soils, that up to 98 percent of the rainfall runs off. Runoff moves as sheet flow or becomes concentrated in rills and gulleys. It is dynamic in that it has energy to erode and transport soil particles. If available energy is greater than the sediment load being carried, the moving water will erode to obtain additional sediment. If the load is greater, deposition of transported material will occur.

Normally, runoff builds up rapidly to a peak and then diminishes. Excess quantities of sediment are derived by erosion principally during higher flows. During lower flows, as runoff velocities decrease, the transported materials are deposited to be picked up by subsequent high flows. In this way, sediments are carried downstream intermittently from the source area. One study of sedimentation due to road construction and land development showed that 99 percent of the sediment discharged occurred during periods of high flow which took place during only 3 percent of the measured period.

Effects of Excessive Sediment Loads. Over one billion tons of sediment reach the rivers of our country each year. Approximately 10 percent of this quantity is contributed by erosion from lands undergoing road construction and land development. Although the quantities may be small compared to the total, they could represent over one-half of the sediment loads carried by streams draining small watersheds under development. For very small areas, where construction activities have altered the soil mantle and vegetative cover, sediment derived from one acre of land may exceed 20,000 to 40,000 times that obtained from adjacent farm or undeveloped lands in an equivalent period of time.

Wherever the velocity of streams carrying sediment decreases, deposition occurs. The excessive quantities of sediment cause costly damage to riparian areas and to public and private lands. Obstruction of stream channels by masses of deposited materials reduces their hydraulic capacity which, in turn, causes an increase in flood heights and a consequent increase in damages. Sediments often fill drain ditches along roads and railroads, and plug culverts and storm sewers. Damage to drill sites, roads and pipelines from sediments and subsequent erosion often hinder or even prevent company operations and are costly to repair. Such sediments also affect offsite resources. Municipal water supply and livestock watering reservoirs lose storage capacity, and the cost of filtering the muddy water for municipal supplies becomes excessive. The added expense of water purification amounts to millions of dollars each year. The aesthetic attraction of many lakes and reservoirs used for swimming, boating, fishing, and other water-related activities is reduced greatly. To remove these deposits and repair the damage involved can be very costly.

The general effect of fine-grained sediments such as silts and fine sands in an aquatic environment is to drastically reduce both the kinds of organisms present and their total number. The sediments alter the existing environment by screening out sunlight and changing the heat radiation. As particles settle to the bottom, they form a blanket which creates an undesirable environment for organisms which normally occur. It often smothers developing eggs of fish and also other organisms. Coarser-grained materials also blanket bottom areas to supress bottom life. Where currents become strong, the abrasive action of these materials can have severe effects on the plants and animals on the bottom.

Other adverse effects of excessive sediment deposition on the stream systems or on downstream receiving waters can result from nutrients or pollutants which may be adsorbed on fine-grained soil particles. Nutrients such as phosphorus and nitrogen are often released due to disturbances to the site's topsoil and subsoil. These nutrients can cause accelerated eutrophication (enrichment) of waters with the accompanying increases in algal and vascular plant nuisances, foul odors, and water treatment problems. Organic matter such as fatty acids, higher-order alcohols, and products of plant life also may be adsorbed by soil particles to contribute to displeasing taste and odor in water supplies. Several cities in the Rocky Mountain area, such as those along Colorado's Front Range (e.g., Denver) have periodically stopped all types of land development because of the disagreeable taste of the water reaching downstream reservoirs.

THE RECLAMATION PRACTICES MATRIX

Given the short-term goal of controlling erosion and the long-term goal of establishing wildlife habitat, a reclamation practices matrix (Table 1) has been developed which identifies reclamation activities that should be utilized to effectively meet these objectives. The matrix attempts to identify methods or techniques that have been proven effective for the Bear River Divide region. These practices of necessity must vary with environmental conditions. The matrix is designed to be utilized as a simple key and to provide an easy method of selecting the best reclamation practices for a given site.

These techniques are listed within the matrix in a coded format so that the matrix is compact and easily readable. The codes are described and the techniques more fully explained in the Reclamation Practices section of the manual. Once a technique is selected, the user should read that section of the Reclamation Practices to better understand not only the technique but the purpose for its application. When no single technique is clearly superior then multiple techniques are listed and the user can select the technique that is most appropriate for specific site conditions.

Special site conditions may make a specified technique in the matrix impossible and the operator or regulator should anticipate that changes will occur. The matrix is not intended to be the sole authority on appropriate techniques. Rather, it is to be used as a general guide with allowances for site specific conditions.

The matrix is segregated by major parameters that are intended to characterize the site so that appropriate reclamation techniques can be selected. These parameters have been selected based on field observations and data presented in Appendix II (OIA 1985). The four parameters are moisture regime/vegetation type, soil type, slope and priority. The field study identified the first three of these parameters as major environmental factors that influenced successful revegetation. Revegetation was possible on all the sites observed during the field studies but success was dependent on the application of proper reclamation techniques. The following is a discussion of these parameters, why they were selected and how the user is to select levels within each parameter.

Moisture Regime/Vegetation Type

The first decision facing the user is in which moisture regime/vegetation type the site is located. For ease in using the matrix, the moisture categories have been divided into only three groups; these are moist, intermediate and dry. Since many of the revegetation practices do not vary substantially between moisture regimes, for clarity, these factors have been included as footnotes in the matrix. Separate seed mixes are recommended for each regime/vegetation type. Vegetation types which are classified under the moist category are aspen, conifer and mountain shrub. These vegetation types are usually found on north or east slopes, at higher elevations and in areas where snow accumulates. These vegetation types are generally very important for wildlife as sources of food and cover.

Reclamation Practices

Soil Type	Slope	Priority	Site Clearing	Water Management	Site Preparation	Seeding	Planting	Mulching	Fertilization	Monitoring and Maintenance	Special Problems
Heavy	>3:1	High	X	ID, TR or CF or WB	SC	HB or HS, HR	X	E or S, C	HB or HF	HI	X
		Low	X	ID, TR or CF or WB	SC	HB or HS		S, T	HB or HF	HI	X
	3:1-5:1	High	X	ID, WB or CF	RP or DS	D or B,H	X	S, CR	B	HI	X
		Low	X	ID, WB or CF	RP or DS	D or B,H[3]		S, CR	B	L	X
	5:1-7:1	High	X	ID, CF or WB	RP or DS	D or B,H	X	S, CR	B	HI	X
		Low	X	ID,CF or WB	RP or DS	D or B,H[3]		S, CR[4]	B	L	X
	<7:1	High	X	ID,RP or WB	RP or DS	D or B,H	X	S, CR[4]	B	HI	X
		Low	X	ID,RP or WB	RP or DS	D or B,H		S, CR[4]	B	L	X
Loamy	>3:1	High	X	ID, TR or CF or WB	SC	HB or HS, HR	X	E or S, C	HB or HF	HI	X
		Low	X	ID, TR or CF or WB	SC	HB or HS		S, T	HB or HF	HI	X
	3:1-5:1	High	X	ID, WB or CF	RP or DS	D or B,H	X	S, CR	B	HI	X
		Low	X	ID, WB or CF	RP or DS	D or B,H[3]		S, CR	B	L	X
	5:1-7:1	High	X	ID, WB or CF	RP or DS	D or B,H	X	S, CR	B	HI	X
		Low	X	ID, WB or CF	RP or DS	D or B,H[3]		S, CR[4]	B	L	X
	<7:1	High	X	ID, WB or CF	RP or DS	D or B,H	X	S, CR[4]	B	HI	X
		Low	X	ID, WB or CF	RP or DS	D or B,H[3]		S, CR[4]	B	L	X
Sandy	>3:1	High	X	ID, TR or CF or WB	SC	HB or HS, HR	X	E or S, C	HB or HF	HI	X
		Low	X	ID, TR or CF or WB		HB or HS		S, T	HB or HF	HI	X
	3:1-5:1	High	X	ID, CF or WB	RP or DS	D or B,H	X	S, CR	B	HI	X
		Low	X	ID, CF or WB	RP or DS	D or B,H[3]		S, CR	B	L	X
	5:1-7:1	High	X	ID, CF[1] or WB	RP or DS	D or B,H	X	S, CR	B	HI	X
		Low	X	ID, RP[2] or WB	RP or DS	D or B,H[3]		S, CR[4]	B	L	X
	<7:1	High	X	ID, WB	RP or DS	D or B,H	X	S, CR[4]	B	HI	X
		Low	X	ID, WB	RP or DS	D or B,H[3]		S, CR[4]	B	L	X
Rocky	>3:1	High	X	ID, TR or WB		HB or HS	X	E or S, C	HB or HF	HI	X
		Low	X	ID, TR or WB		HB or HS		S, T	HB or HF	HI	X
	3:1-5:1	High	X	ID, CF or WB	RP	B	X	S, CR or T	B	HI	X
		Low	X	ID, CF or WB	RP	B		S, CR or T	B	L	X
	5:1-7:1	High	X	ID, RP[2] or WB	RP	B	X	S, CR or T	B	HI	X
		Low	X	ID, RP[2] or WB	RP	B		S, CR or T[4]	B	L	X
	<7:1	High	X	ID, WB	RP	B	X	S, CR or T[4]	B	HI	X
		Low	X	ID, WB	RP	B		S, CR or T[4]	B	L	X

B = broadcast, C = plastic netting, CF = contour furrow, CR = crimping, D = drill, DS = disking, E = excelsior, H = harrow, HB = hand broadcast, HF = hydrofertilize, HI = high, HR = hand rake, HS = hydroseed, ID = interceptor ditch, L = low, RP = contour ripping, S = straw or hay, SC = slope chain, T = tackifier, TR = terrace, WB = water bar, X = should be considered,

[1] = under moist regime/vegetation types contour ripping should be substituted for contour furrows,
[2] = under dry regime/vegetation types contour furrows should be substituted for contour ripping,
[3] = under moist regime/vegetation types harrowing is not necessary,
[4] = under moist regime/vegetation types straw and crimping is not necessary.

The intermediate moisture regime is characterized by juniper, grassland and sagebrush vegetation types. These are generally the areas where most of the oil/gas related disturbances have occurred in the Bear River Divide region. They also represent the dominant vegetation of the area.

The dry moisture regime is characterized by the salt desert shrub vegetation type. This type is very limited in the study area and occurs mostly in eastern Uinta and Lincoln counties. This type is often used as winter range for larger mammals.

Soil Type

Another major factor that was shown to influence reclamation success was soil type or soil texture. The next decision for the user is to select the type of soil occurring on the site within the moisture regime/vegetation type selected. The soil types have been divided into four broad categories: heavy, loamy, sandy and rocky. Heavy soils generally have a high percentage of clay in their textural analysis. These soils are usually listed as clays or clay loams in a soil analysis and are quite common in the Bear River Divide region. The loamy category is composed of soils with a good mix of sand, silt and clay particles. These are generally the best soils for reclamation and are also fairly common in their distribution in the study area. Sandy soils have a high percentage of sand, hold less water and are quite erodible making revegetation difficult. The final soil type is rocky. Rocky soils are often encountered in areas where topsoils are very thin and the parent materials or bedrock is near the surface.

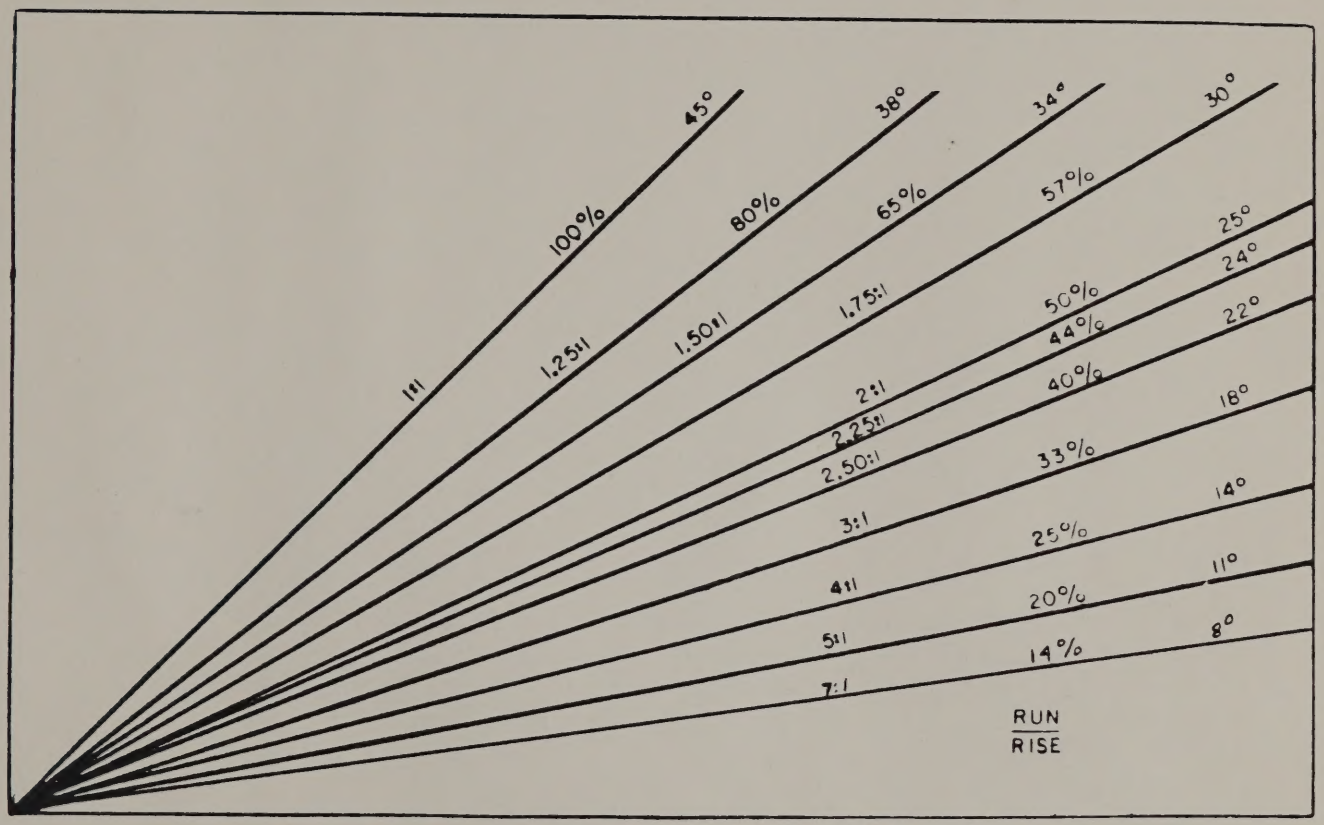
Slopes

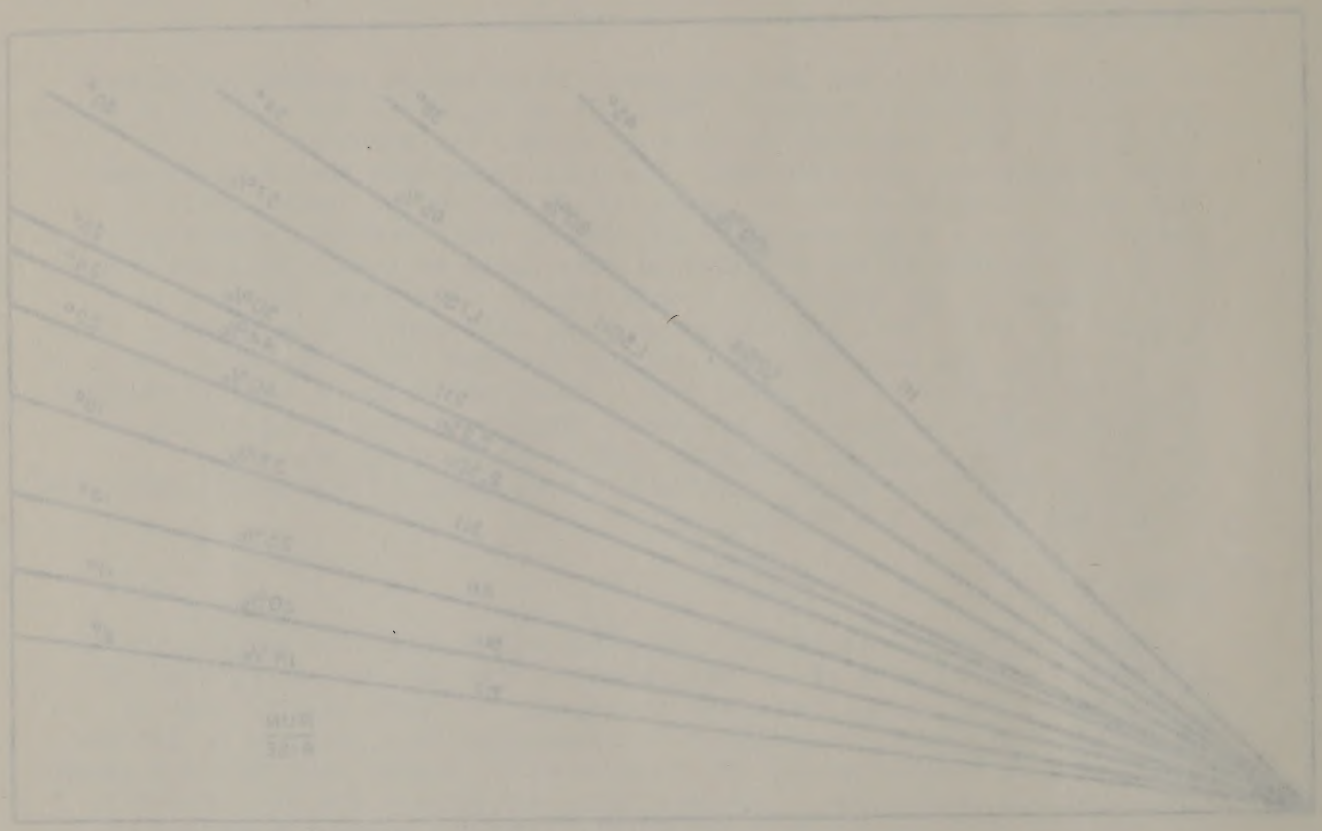
The steepness of slopes is a very important factor in determining the erosion potential of a site. The matrix recognizes four categories of slope steepness. These divisions were based on field observations of erosion and reclamation equipment requirements, i.e., wheeled or tracked vehicles have limited access on the contour of slopes less than 3:1 except under optimum conditions. The four slope categories are >3:1, 3:1-5:1, 5:1-7:1 and <7:1 (horizontal:vertical). Figure 1 shows a graphical depiction of these slopes and a conversion table to percentages which are commonly used.

Priority

The last major parameter in the matrix is that of priority of the site. Only two ratings are given for this parameter, high and low. The priority rating is subjective and thus it is important that it is made by the operating company with inputs from the land owner or steward. Examples of the high priority rating would be a highly visible site, a site near a perennial stream or lake, or a site in or near critical winter range for a wildlife species.

Figure 1. Comparisons of different measures of slope gradients.





RECLAMATION PRACTICES

SITE SELECTION AND EVALUATION

The selection of site disturbance locations should consider the potential for successful reclamation as much as possible. Reclamation costs increase on harsher sites because these sites require unique reclamation practices or because the standard reclamation practices are more difficult to implement. In addition, areas classified as high priority will often require more expensive reclamation techniques. These factors should be considered prior to initiating a disturbance in order to minimize or eliminate disturbances in problem areas where possible. Some of the specific factors that should be considered are listed below.

Areas of Snow Accumulation

Areas of heavy snow accumulation require extra maintenance for accessibility during the winter. Reclaimed slopes that receive excessive snow packs are more susceptible to slumping and erosion following snow melt. Snow that is piled on the pad or pushed over the edge of a pad causes erosion following snow melt. Areas of heaviest snow accumulation along the Bear River Divide Area are associated with aspen vegetation types.

Areas with Steep Slopes

As indicated in the revegetation matrix, areas with slopes steeper than 3:1 require special attention because they are more difficult to revegetate and the erosion potential is much greater.

Heavy Clay Soils

These soils are of marginal suitability as a plant growth medium, are easily compacted and are difficult to prepare as a good seedbed. These soils are often associated with ridgetops along the Bear River Divide.

Extremely Windy Sites

These sites are associated with ridgetops and often have shallow or clayey soils. Because of their exposure, they are susceptible to drying, moisture falling as snow is blown away and therefore not available for plants, and seed materials can also be blown away.

Critical Wildlife Habitat

Riparian zones should be avoided. This is not a major problem for drill sites in the Bear River Divide region but pipeline and road corridors may intersect these areas. Aspen and juniper areas provide an important habitat and disturbance in these areas should be minimized. Critical wildlife habitats of the Bear River Divide and adjacent areas have been mapped and the reader should refer to these maps prior to development (OIA

in press).

Areas Sensitive to Sediment Pollution

Drainage and water systems are susceptible to increased sediment from site construction. Construction near these areas will require more extensive sediment control facilities.

Highly Visible Areas

Negative publicity is possible from highly visible areas. To minimize the length of time impacts are visible, more expensive reclamation techniques may be required.

SITE CLEARING AND PREPARATION

Site clearing consists of removing large shrubs and trees and removing available topsoil to be used later in reclamation. By minimizing the disturbance during site clearing, less soil resource is lost and more rapid recovery is possible. Topsoil provides numerous benefits to vegetation establishment over the use of subsoil including increased infiltration, improved nutrient status, improvement in the availability of essential soil microorganisms, and a greater supply of native seed and plant propagules. Topsoil results in better vegetation diversity, production and cover and therefore results in better erosion control and lower sediment yields. Topsoil handling comprises a large portion of the entire cost of reclamation and therefore should be utilized wisely.

Description of Techniques

Site disturbance should be minimized as much as possible during construction. Often in clearing rights-of-way for pipelines, excessive vegetation and soil is removed. Vegetation should be removed to the minimum width possible to allow construction of the pipeline. By minimizing the disturbance of vegetation and soil resources during construction, many plant species important to wildlife can reestablish more quickly from reserve seed and plant materials in the soil. This will greatly enhance vegetative diversity on reclaimed areas and allows the establishment of species that may not be available as commercial seed or that may be difficult to establish from seed.

A brush rake is well suited to removing and piling large brush and slash and should be used when possible. It is superior to a standard dozer blade because soil is filtered through the rake and not scraped into the brush piles. Thus, soil disturbance and loss is minimized when removing vegetation. Brush rakes consist of several curved teeth attached vertically to a heavy-duty frame and often have replaceable tips to protect the rake teeth. Brush rakes usually replace the standard dozer blade but some can be attached directly to the standard dozer blades.

Brush beaters or rolling choppers such as the Rotoclear work well for grinding or chopping shrubs and trees into the soil thus eliminating the need for specific brush removal. This increases the seed source and provides a mulch. It has shown particular promise along pipelines.

Scrapers can generally move topsoil cheaper than dozers, but they require higher mobilization costs. Skelly and Loy (1975) indicated that the major factor affecting cost is haulage distance. They stated that dozers and loaders are only economical for haulage distances ranging from 100 to 200 feet, and 200 to 500 feet respectively. For distances greater than 500 feet costs increase rapidly. As haulage increases to 700 feet and higher, trucks or scrapers become more economical. The cost of using scrapers is less than trucks for distances between 700 and 1300 feet and relatively similar for distances greater than 1300 feet. However, scrapers may be temporarily unavailable for a job and as a result higher dozer costs may be necessary.

Generally, because of the limited topsoil available in the Bear River Divide region, all available topsoil should be salvaged. Table 2 outlines criteria for determining suitability of topsoil or topsoil substitutes as outlined by the Wyoming Department of Environmental Quality (Guideline No. 1, 1984). Most of the soils in the Bear River Divide region fall within the suitable category. Some of the clay ridges would fall within the marginally suitable class. Disturbance of these sites should be avoided because revegetation will be more difficult. In the event of a lack of alternatives, marginally suitable topsoil can be used.

Topsoil should be handled while it is relatively dry to avoid excessive compaction. Handling under windy conditions should be avoided to minimize wind erosion and dust emissions. If this is not possible, procedures to minimize fugitive dust may be necessary.

Rapid redistribution of topsoil will enable better use of the seed and plant propagule reserves in the topsoil, thus encouraging rapid recolonization by native species. This can greatly augment the establishment of shrubs and trees that are important to wildlife but are difficult to establish from seed. Plants such as snowberry, aspen, and wild rose will resprout from plant materials left in the soil. Stockpiling topsoil, although necessary for long-term reclamation of producing well sites, reduces the amount of viable plant and seed materials and microorganisms in the topsoil.

Stockpiled topsoil must be protected from wind and water erosion. Interceptor ditches, described in the water management section, should be used to protect stockpile areas. These areas should be marked and vehicular traffic should be excluded from them. Topsoil piles should be seeded if they will exist for longer than one growing season.

Table 2: Criteria to establish suitability of topsoil (or topsoil substitutes). (Wyoming DEQ, Guideline No. 1, 1984)

Parameter	Suitable	Marginal 1/	Unsuitable
pH 2/	5.5-8.5	5.0-5.5 8.5-9.0	<5.0 >9.0
EC (Conductivity) 3/ mmhos/cm	0-8	8-12	>12
Saturation Percentage 4/	25-80	<25 >80	
Texture		Clay, silty clay, sand	
SAR 5/	0-10	10-12 6/ 10-15	>12 6/ 15
Selenium	<0.1 ppm	>0.1 ppm	
Boron	<5.0 ppm		>5.0 ppm
Coarse Frag (% vol)	<25%	25-35	>35%

1/ Evaluated on an individual basis for suitability

2/ A measurement of Hydrogen ion activity, an index of acidity.

3/ A measurement of the soluble salts or salinity of a soil.

4/ The amount of water necessary to saturate a dried soil. A high percentage is indicative of clayey soils.

5/ Sodium Absorption Ratio - expresses the relative activity of sodium exchange reactions of the soil, and reflects the potential sodic hazard. As an alternative to SAR calculations, ESP (exchangeable sodium percentage) can be determined. ESP should be determined if suitable SAR value is exceeded.

6/ For fine textured soils (clay >40%).

WATER MANAGEMENT

Erosion from construction sites and drill pads both during and after construction often produces severe adverse impacts to water quality and destroys important habitat for wildlife and livestock. "Water pollution, caused by erosion, causes contamination of critical food chains for wildlife, destroys aquatic life, and presents dangers to public health, safety, and welfare through the transmission of bacteria and other disease related organisms."(Salt Lake County, 1981).

Section 208 of the Federal Clean Water Act (1977), requires that local governments identify the nature and extent of non-point pollution from various sources, and also that regulatory programs be implemented to abate or reduce pollution so as to regain or maintain the beneficial use for the nation. In addition, Federal land agencies such as the Soil Conservation Service, Bureau of Land Management, Forest Service, etc. are charged with the responsibility of limiting erosion on lands for which they are responsible.

Some erosion from any given site is natural and ecosystems can adjust to this type of erosion. However, construction activities greatly increase the potential for erosion. It is important to understand the factors influencing the rate of erosion so as to keep erosion at a minimum. These factors include rainfall, soils, slope gradient, length of slope and vegetative cover. These factors form the basis for the reclamation matrix and provide the key for identifying appropriate reclamation techniques. Construction activities which disturb any of the above factors will generate sediment loads greatly in excess of natural conditions. Appendix II (OIA 1985) identified that water movement onto a site and from a site was a serious problem and led to considerable erosion problems. Thus water management was identified as an important factor in site reclamation and should be a major component of any reclamation plan for the Bear River Divide and adjacent areas. Before any construction is conducted, the construction manager should plan out the needed erosion/water management measures. These measures should be incorporated in the construction plans and drawings, not put in place as an after thought. The plan should include all steps necessary, including scheduling of erosion/sediment control measures, to ensure proper erosion/sediment control during all phases of the project.

Because of the greater degree of success in erosion control on flatter slopes, it is usually advisable to flatten slopes as much as possible. Given a specific slope, the following techniques can be used to minimize erosion.

Criteria for Selection of Techniques

The following description of techniques and specifications are provided to enable the design of water management plans during the site planning process and as specified by the reclamation matrix. The reclamation matrix identifies possible techniques that should be used under specified conditions. Whether a technique is suitable for a site should be

determined by the specific site condition. The following includes a discussion of the techniques for managing water on site to reduce erosion and enhance the establishment of a stable vegetative cover. Once the techniques have been selected from the matrix and further refined by specific site conditions then general specifications can be obtained from the following section. Figure 2 shows a composite drawing of the application of several water management techniques as they might be appropriately applied to a drill site.

Interceptor Ditch (Diversion Dike). An interceptor ditch (ID) is an excavated drainageway and/or temporary ridge of compacted soil (berm) immediately above cut or fill slopes and constructed with sufficient grade to provide drainage. The purpose of an interceptor ditch is to intercept storm runoff from small upland areas and divert it from exposed slopes to an acceptable outlet. The interceptor ditch is used to prevent excessive erosion until permanent drainage features are installed and/or slopes are stabilized. Generally, excavated drainageways are used to protect cut slopes while excavated drainageways or berms are used to protect fill slopes.

Interceptor ditches should be used on all sites where there is a potential for water to flow onto a disturbed site. Examples of sites not requiring interceptor ditches are sites located on the tops of hills or on level ground.

Contour Furrow. A contour furrow (CF) is a an excavated drainageway and/or a temporary ridge of compacted soil generally located on moderate slopes. The purpose of a contour furrow is to shorten the length of exposed slopes, thereby reducing the potential for erosion. The contour furrow intercepts storm runoff and diverts it across the slope to a stabilized outlet or sediment trapping device, often stabilized natural vegetation. Contour furrows are generally constructed across large disturbances such as drill pads or production facilities. The furrows remain in place until the disturbed areas are permanently stabilized.

Terraces or Land Grading. Terracing (TR) involves the reshaping of the existing topography to slow water movement. Terraces are desired to reduce the slope length and channel any runoff across the slope to a stabilized outlet. The purpose is to provide protection from erosion and for vegetative establishment on those areas where the existing topography is too steep for other techniques or for equipment.

Water bars. A water bar (WB) is an excavated drainageway and a temporary ridge of compacted soil located across disturbed areas or rights-of-way. The purpose of water bars is to shorten the length of exposed slopes, thereby reducing the potential for erosion, by intercepting storm runoff and diverting it to a stablized outlet or sediment trapping device. Water bars are most commonly used on linear disturbances such as pipelines and roads. The water bars should be designed to remain in place until the disturbed areas are permanently stabilized.

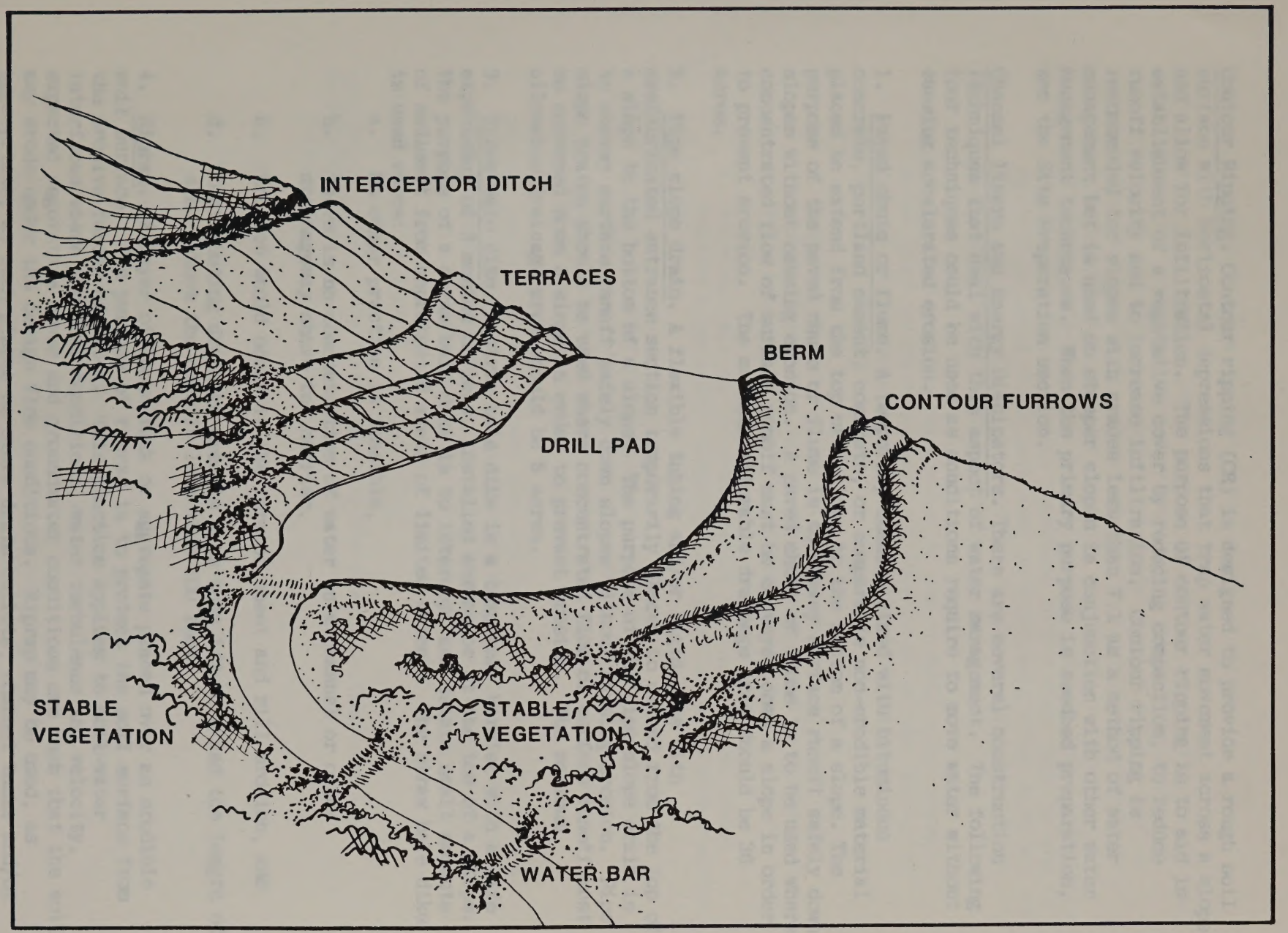
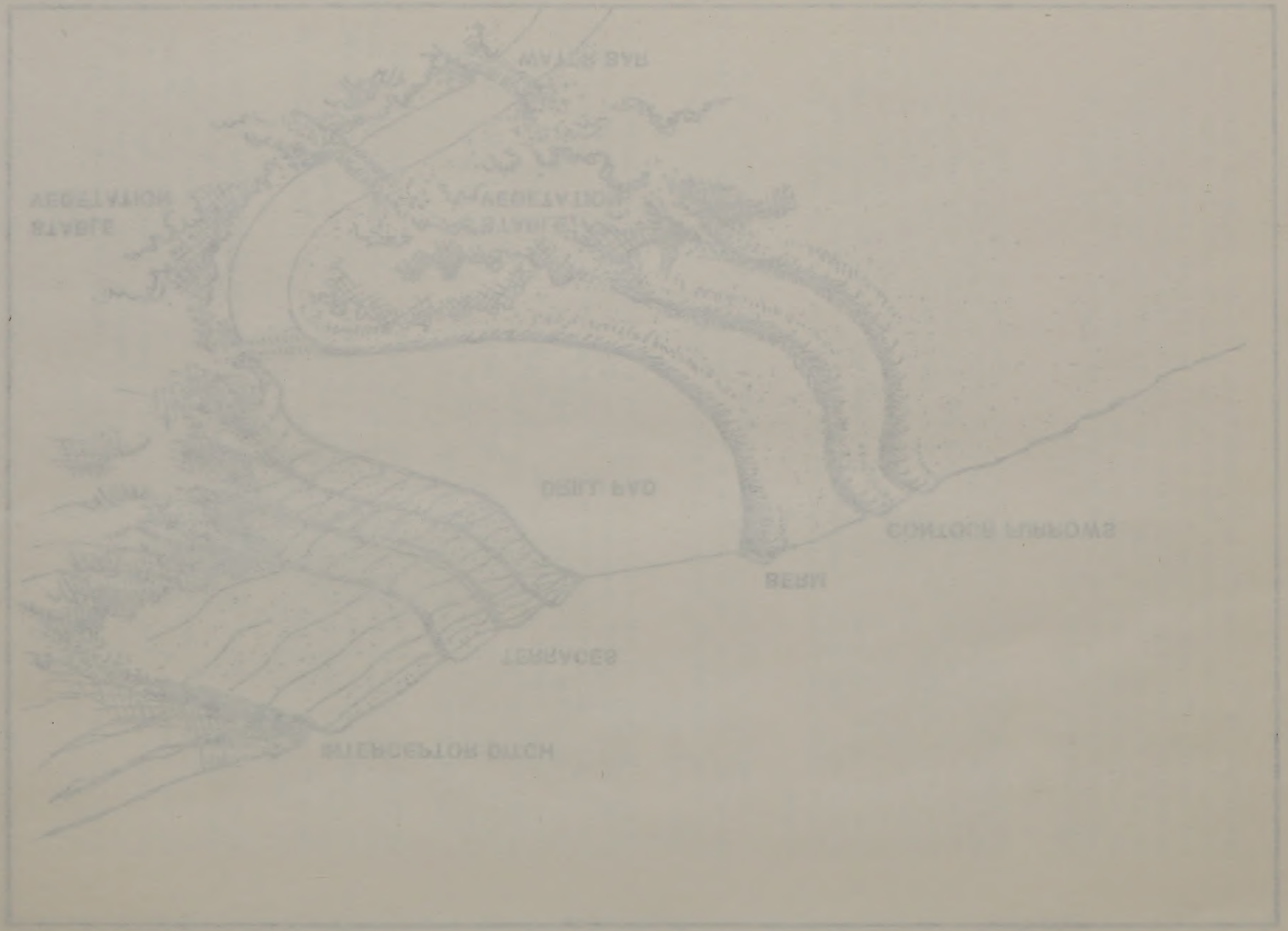


Figure 2. Composite drawing showing several water management techniques utilized on a drill site.



Contour Ripping. Contour ripping (CR) is designed to provide a rough soil surface with horizontal depressions that trap water movement across a slope and allow for infiltration. The purpose of contour ripping is to aid in establishment of a vegetative cover by reducing compaction, to reduce runoff velocity and to increase infiltration. Contour ripping is recommended for slopes with grades less than 7:1 as a method of water management but is used on steeper slopes in conjunction with other water management techniques. When the primary purpose is seedbed preparation, see the Site Preparation section.

Channel liners and Energy Dissipators. There are several construction techniques that deal with this aspect of water management. The following four techniques could be used as conditions require to move water without causing accelerated erosion.

1. Paved chute or flume. A temporary channel lined with bituminous concrete, portland cement, concrete, or comparable non-erodible material placed to extend from the top of a slope to the bottom of a slope. The purpose of the paved chute or flume is to convey surface runoff safely down slopes without causing erosion. A paved chute or flume is to be used where concentrated flow of surface runoff must be conveyed down a slope in order to prevent erosion. The maximum allowable drainage area should be 36 acres.

2. Pipe slope drain. A flexible tubing and/or rigid pipe with prefabricated entrance section temporarily placed to extend from the top of a slope to the bottom of a slope. The purpose of the pipe slope drain is to convey surface runoff safely down slopes without causing erosion. Pipe slope drains should be used where concentrated flow of surface runoff must be conveyed down a slope in order to prevent erosion. The maximum allowable drainage area should be 5 acres.

3. Straw bale dike. A straw bale dike is a temporary barrier with a life expectancy of 3 months or less, installed across or at the toe of a slope. The purpose of a straw bale dike is to intercept and detain small amounts of sediment from unprotected areas of limited extent. The straw bale dike is used where:

   a. No other practice is feasible,

   b. There is no concentration of water in a channel or other drainageway above the barrier,

   c. Erosion would occur in the form of sheet and rill erosion, and

   d. Contributing drainage area is less than 1/2 acre and the length of slope above the dike is less than 100 feet.

4. Riprap. A layer of loose rock or aggregate placed over an erodible soil surface. The purpose of riprap is to protect the soil surface from the erosive forces of water. This practice applies to soil-water interfaces where the soil conditions, water turbulence and velocity, expected vegetative cover and groundwater conditions are such that the soil may erode under the design flow conditions. Riprap may be used, as appropriate, at such places as storm drain outlets, channel banks and/or

bottoms, roadside ditches, drop structures and shorelines.

Grade control structures. Grade control structures are used to reduce and maintain channel gradients through reduction of runoff velocities and erosion. Check dams are an example of a grade control and are used to stabilize the grade and control head cutting in natural or artificial channels. Grade control structures include:

1. Drop Structure. Man-made channels which must traverse long, relatively steep slopes without large increases in the flow velocity and in natural channels which have long or relatively steep sections and which, as a result of contruction activities, are expected to experience channel erosion problems.

2. Check Dams. This practice is limited to use in small open channels which drain 10 acres or less. It should not be used in a live stream. Some specific applications are illustrated by the following examples.

   a. Temporary ditches or swales which, because of their short length of service, cannot receive a nonerodible lining but still need some protection to reduce erosion.

   b. Permanent ditches or swales which for some reason cannot receive a permanent nonerodible lining for an extended period of time.

   c. Either temporary or permanent ditches or swales which need protection during the establishment of grass linings. Alternative measures in small drainageways are sediment barriers such as sand and gravel bags.

3. Erosion Checks. Used in areas that are susceptible to rill erosion, such as swales or shallow ditches, or on critical slopes subject to severe sheetflow. They are generally located joints in swales and ditches where the gradient changes or tributary inflow occurs.

General Specifications for Construction

Interceptor Ditch. The following criteria should be used when constructing interceptor ditches:

Drainage area - less than 5 acres

Top width - 2 feet minimum

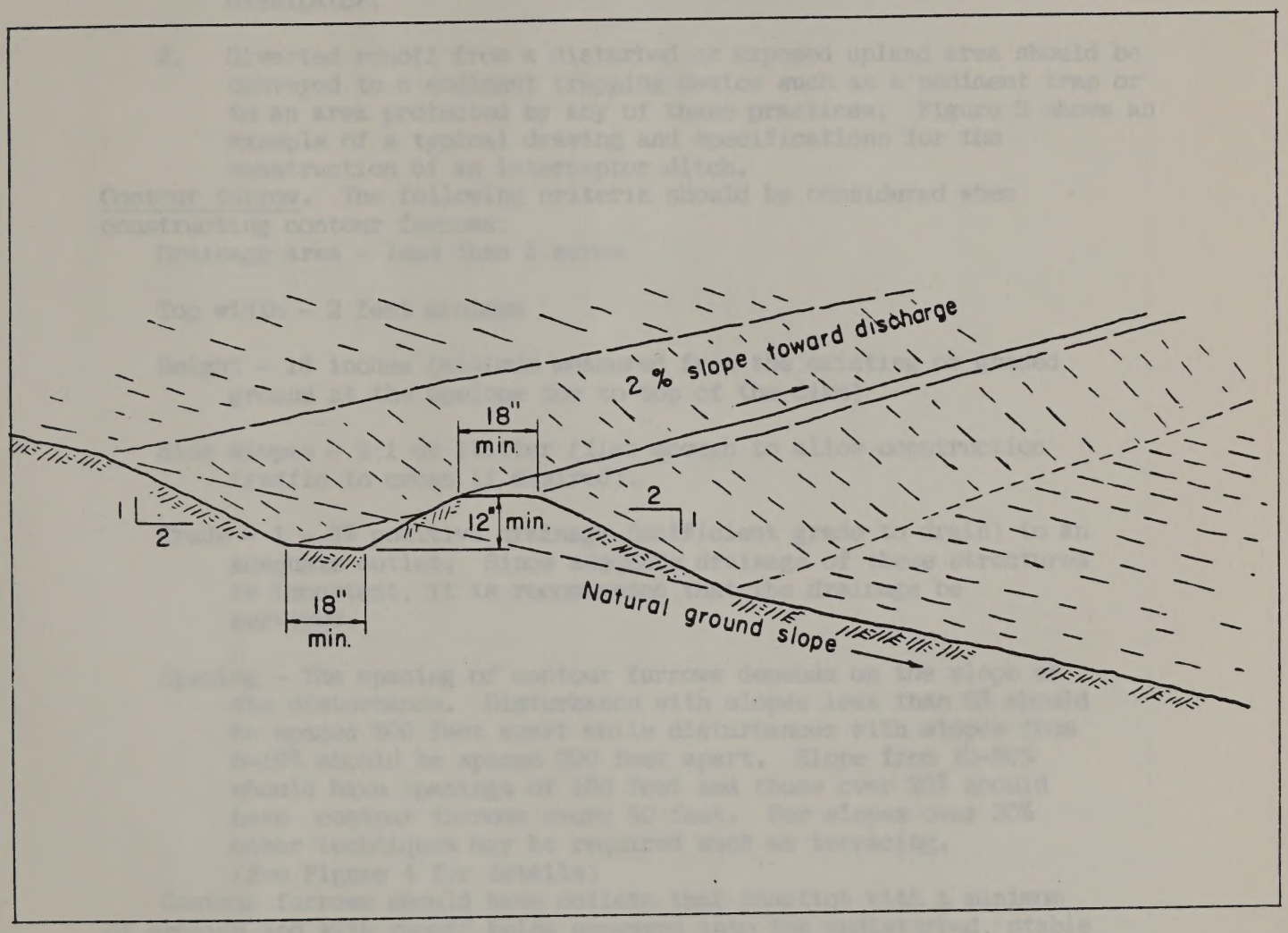
Height - 18 inches minimum (measured from the existing ground at the upslope toe to top of the dike).

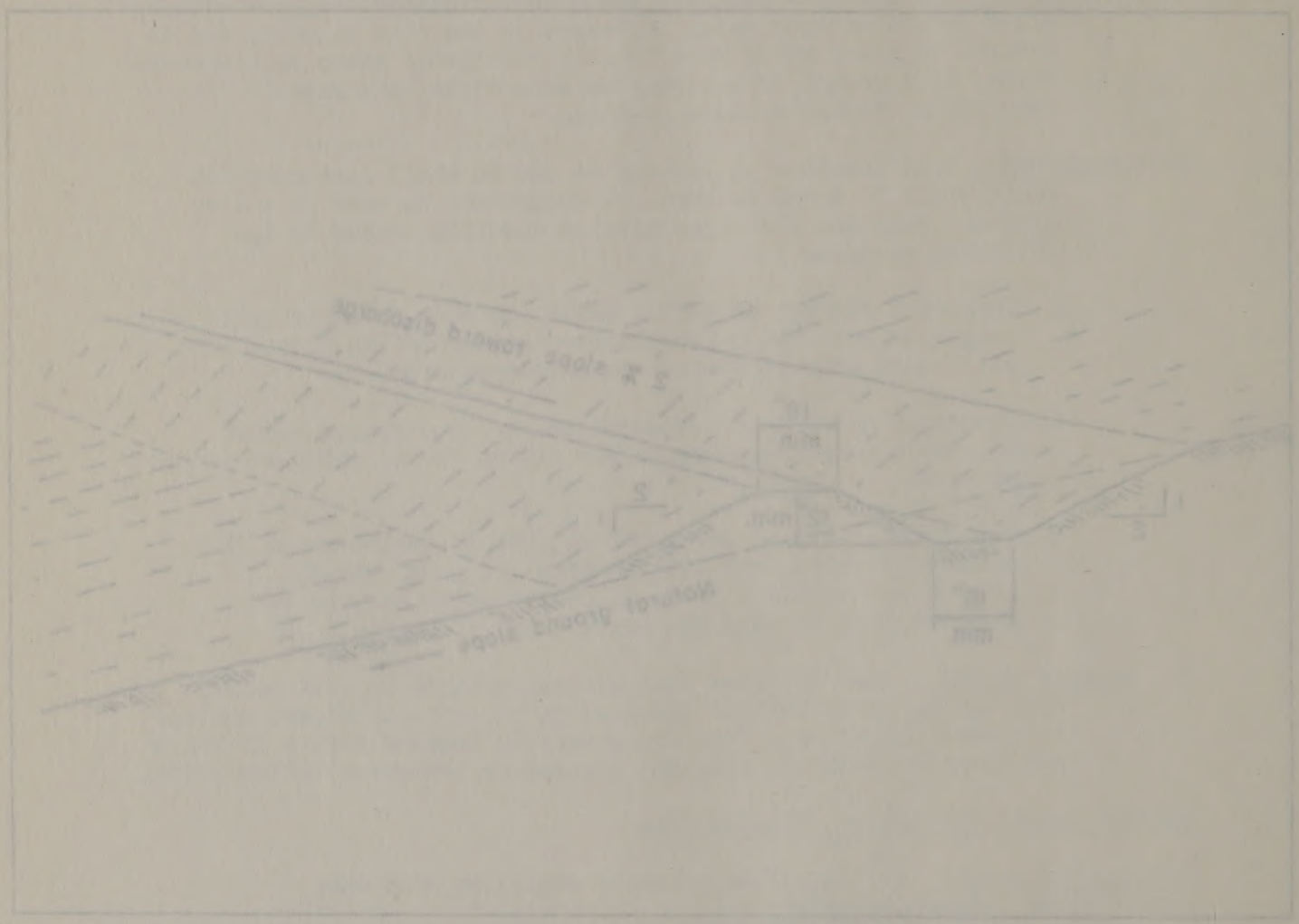
Side slopes - 2:1 or flatter

Grade - dependent upon topography (usually 2-3%) must have positive drainage to an adequate outlet.

Stabilization - where slope of channel (flow area) is:
0-5% - stabilization may be required by the designer

Figure 3. Example of construction specifications for intercept ditches (Tahoe Regional Planning Agency 1978).





according to the needs of the site.
Over 5% - stabilization should be required.

The outlet for the interceptor ditch should include the following:

1. Diverted runoff from a protected or stabilized area should outlet directly to an undisturbed stabilized area or into an energy dissipator.

2. Diverted runoff from a disturbed or exposed upland area should be conveyed to a sediment trapping device such as a sediment trap or to an area protected by any of these practices. Figure 3 shows an example of a typical drawing and specifications for the construction of an interceptor ditch.

Contour furrow. The following criteria should be considered when constructing contour furrows:

Drainage area - less than 5 acres

Top width - 2 feet minimum

Height - 18 inches (minimum measured from the existing or graded ground at the upslope toe to top of the dike)

Side slopes - 2:1 or flatter (flat enough to allow construction traffic to cross if desired).

Grade - 1 - 3% positive drainage (sufficient grade to drain) to an adequate outlet. Since adequate drainage of these structures is important, it is recommended that the drainage be surveyed.

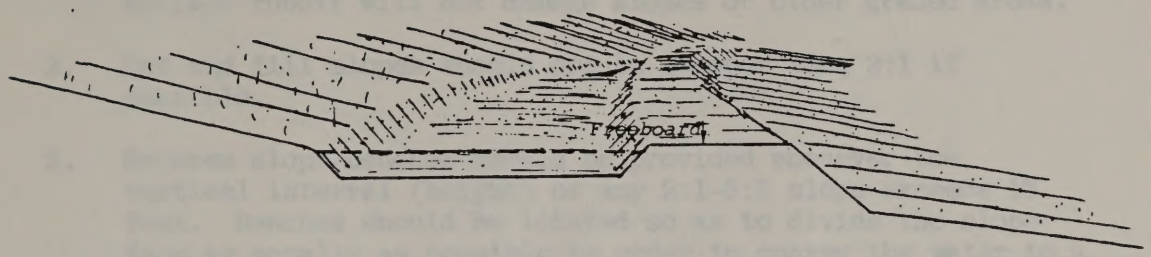
Spacing - The spacing of contour furrows depends on the slope of the disturbance. Disturbance with slopes less than 5% should be spaced 300 feet apart while disturbances with slopes from 5-10% should be spaced 200 feet apart. Slope from 10-20% should have spacings of 100 feet and those over 20% should have contour furrows every 50 feet. For slopes over 30% other techniques may be required such as terracing. (See Figure 4 for details)

Contour furrows should have outlets that function with a minimum of erosion and with runoff being conveyed into the undisturbed, stable vegetation, channel liner or energy dissipator device.

Terraces. The grading plan and installation of terraces should be based upon adequate topographic surveys and investigations. The plan should show the location, slope, cut fill and finish elevation of the surfaces to be graded. The plan should also include auxiliary practices for safe disposal of runoff water, slope stabilization, erosion control and drainage. Facilities such as outlets, diversions and grade stabilization structures, should be included where necessary.

The plan should show existing and proposed contours (preferably 2' contour minimum) of the area(s) to be graded. The plan should also

Figure 4. Example of construction specifications for contour furrows as outlined by USDA (USDA Soil Con. Serv. 1975).



TRAPEZOIDAL CROSS-SECTION



PARABOLIC CROSS-SECTION

Construction Specifications

1. All trees, brush, stumps, obstructions, and other objectionable material shall be removed and disposed of so as not to interfere with the proper functioning of the diversion.
2. The diversion shall be excavated or shaped to line, grade, and cross section as required to meet the criteria specified herein, and be free of irregularities which will inpede normal flow.
3. Fills shall be compacted as needed to prevent unequal settlement that would cause damage in the completed diversion.
4. All earth removed and not needed in construction shall be spread or disposed of so that it will not interfere with the functioning of the diversion.
5. Stabilization shall be done according to the appropriate Standard and Specifications for Vegetative Practices.
   A. For design velocities of less than 3.5 ft. per sec., seeding and mulching may be used for the establishment of the vegetation. It is recommended that, when conditions permit, temporary diversions or other means be used to prevent water from entering the diversion during the establishment of the vegetation.
   B. For design velocities of more than 3.5 ft. per sec., the diversion shall be stabilized with sod, with seeding protected by jute or excelsior matting or with seeding and mulching including temporary diversion of water until the vegetation is established. See the Standard and Specifications for Protective Materials.

Standard Symbol

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE College Park, Md.		



include scheduling and phasing of these practices. The following should be incorporated into the design and installation of terraces:

1. Provisions to safely conduct surface runoff to storm drains, protected outlets or to stable water courses to ensure that surface runoff will not damage slopes or other graded areas.

2. Cut and fill slopes should not be steeper than 2:1 if possible.

3. Reverse slope benches should be provided whenever the vertical interval (height) of any 2:1-5:1 slope exceeds 15 feet. Benches should be located so as to divide the slope face as equally as possible in order to convey the water to a stable outlet. Soils, seeps, rock outcrops, etc., must also be taken into consideration when designing benches. Benches should be wide enough to accomodate the construction equipment in use and provide for ease of maintenance. Benches should be designed with a reverse slope of 5:1 or flatter to the toe of the upper slope and with a minimum of 1 foot in depth. Bench gradient to the outlet is usually between 1% and 2%. It is important that terraces drain properly. Therefore, it is recommended that the terrace drainage be surveyed. The flow length within a bench should not exceed 800' unless accompanied by appropriate design and computation.

4. Surface water should be diverted from the face of the cut and/or fill slopes by the use of interceptor ditches or conveyed downslope by the use of a designed structure where overland flow is anticipated.

5. The cut face of earth excavations and fills should not be steeper than the safe angle to repose for the materials encountered and flat enough for proper maintenance.

6. The permanently exposed faces of earth cuts and fills should be vegetated or otherwise protected from erosion.

7. Subsurface drainage should be be provided in areas having a high water table, to intercept seepage that would adversely affect slope stability, or create undesirable wetness.

8. Vegetation which is not to be disturbed by the grading should be protected from mechanical damage and undesirable changes in the water table, subsurface aeration, surface or subsurface drainage, or other induced changes.

9. Fill material should be free of brush, rubbish, timber, logs, stumps or other vegetative matter, in amounts that will be detrimental to constructing stable fills.

10. All fills should be compacted sufficiently for their intended purpose and as required to reduce slipping, erosion or excess

include scheduling and phasing of these practices. The following should be incorporated into the design and installation of terraces:

1. Provisions to safely conduct surface runoff to storm drains, protected outlets or to stable water courses to ensure that surface runoff will not damage slopes or other graded areas.

2. Cut and fill slopes should not be steeper than 2:1 if possible.

3. Reverse slope benches should be provided whenever the vertical interval (height) of any 2:1-8:1 slope exceeds 15 feet. Benches should be located so as to divide the slope face as equally as possible in order to convey the water to a stable outlet. Soils, seeps, rock outcrops, etc., must also be taken into consideration when designing benches. Benches should be wide enough to accommodate the construction equipment in use and provide for ease of maintenance. Benches should be designed with a reverse slope of 5:1 or flatter to the top of the upper slope and with a minimum of 1 foot in depth. Bench gradient to the outlet is usually between 1% and 2%. It is important that terrace drain properly. Therefore, it is recommended that the terrace drainage be surveyed. The flow length within a bench should not exceed 800' unless accompanied by appropriate design and computation.

4. Surface water should be diverted from the face of the cut and/or fill slopes by the use of interceptor ditches or conveyed downslope by the use of a designed structure where overland flow is anticipated.

5. The cut face of earth excavations and fills should not be steeper than the safe angle to impose for the materials encountered and flat enough for proper maintenance.

6. The permanently exposed faces of earth cuts and fills should be vegetated or otherwise protected from erosion.

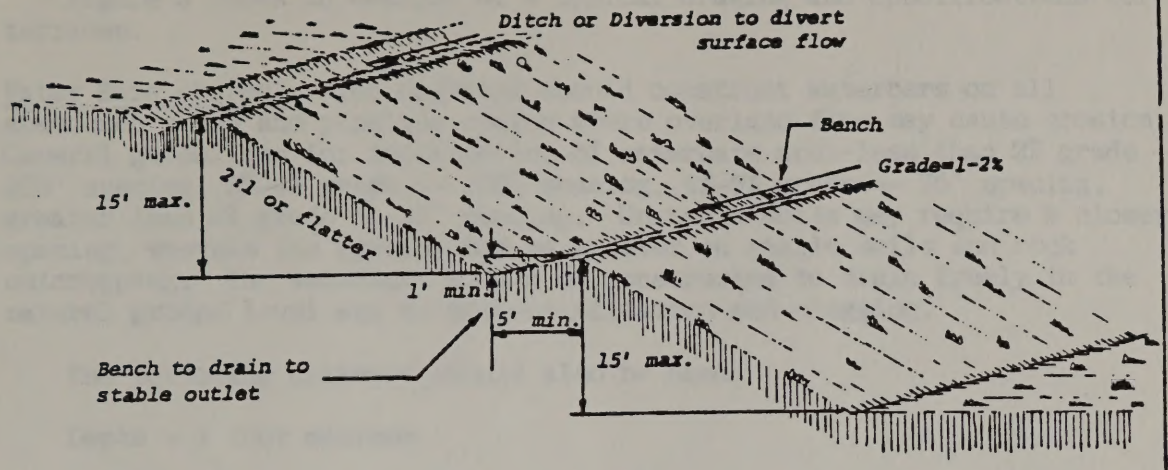
7. Subsurface drainage should be be provided in areas having a high water table, to intercept seepage that would adversely affect slope stability, or create undesirable wetness.

8. Vegetation which is not to be disturbed by the grading should be protected from mechanical damage and undesirable changes in the water table, subsurface aeration, surface or subsurface drainage, or other induced changes.

9. Fill material should be free of brush, rubbish, timber, logs, stumps or other vegetative matter, in amounts that will be detrimental to constructing stable fills.

10. All fills should be compacted sufficiently for their intended purpose and as required to reduce slipping, erosion or excess

Figure 5. Example of construction specifications for terraces as outlined by USDA (USDA Soil Con. Serv. 1975).

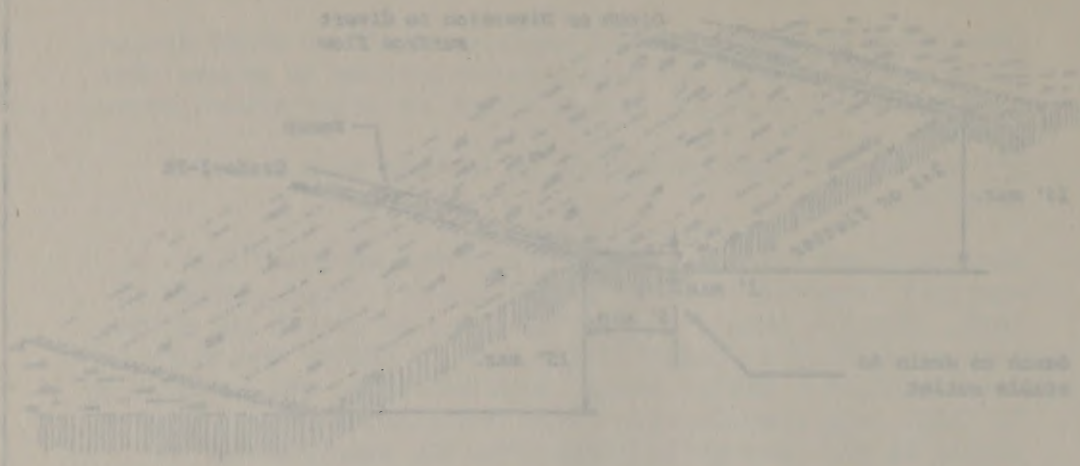


SLOPE DETAIL (WITH BENCH)

Construction Specifications

1. All graded or disturbed areas including slopes shall be protected during clearing and construction in accordance with the approved sediment control plan until they are permanently stabilized.
2. All sediment control practices and measures shall be constructed, applied and maintained in accordance with the approved sediment control plan and the "Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas".
3. Topsoil required for the establishment of vegetation shall be stockpiled in amount necessary to complete finished grading of all exposed areas.
4. Areas to be filled shall be cleared, grubbed and stripped of topsoil to remove trees, vegetation, roots or other objectionable material.
5. Areas which are to be topsoiled shall be scarified to a minimum depth of three inches prior to placement of topsoil.
6. All fills shall be compacted as required to reduce erosion, slippage, settlement, subsidence or other related problems. Fill intended to support buildings, structures and conduits, etc., shall be compacted in accordance with local requirements or codes.
7. All fill to be placed and compacted in layers not to exceed 8 inches in thickness.
8. Except for approved landfills, fill material shall be free of brush, rubbish, rocks, logs, stumps, building debris and other objectionable materials that would interfere with or prevent construction of satisfactory fills.
9. Frozen materials or soft, mucky or highly compressible materials shall not be incorporated into fills.
10. Fill shall not be placed on a frozen foundation.
11. All benches shall be kept free of sediment during all phases of development.
12. Seeps or springs encountered during construction shall be handled in accordance with the Standard and Specifications for Subsurface Drain or other approved method.
13. All graded areas shall be permanently stabilized immediately following finished grading.
14. Stockpiles, borrow areas and spoil areas shall be shown on the plans and shall be subject to the provisions of this Standard and Specifications.

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE College Park, Md.		



saturation.

Figure 5 shows an example of a typical drawing and specifications for terraces.

Water Bars (berms). The operator should construct waterbars on all abandoned roads and pipeline routes where overland flow may cause erosion. General guidelines for installation of waterbars are: less than 2% grade -- 200' spacing, 2%-4% grade -- 100' spacing, 4%-5% grade -- 75' spacing, greater than 5% grade -- 50' spacing. Unstable soils may require a closer spacing, whereas the spacing may be greater on stable soils and rock outcropping. The waterbars should be constructed to drain freely to the natural ground level and to prevent siltation and clogging.

The following criteria should also be used:

Depth - 1 foot minimum

Side slopes - 2:1 or flatter (flat enough to allow construction traffic to cross if desired).

Grade - 1% to 3%; must have positive drainage (sufficient grade to drain to an adequate outlet). It is important that these structures drain properly. Therefore, it is recommended that the drainage be surveyed.

Traffic crossings - At points where several or more vehicles cross per day, a drainage dip should be constructed. This is discussed under Miscellaneous Practices.

A water bar should have an outlet that functions with a minimum of erosion. Figure 6 shows typical specifications for water bars.

Contour Ripping. See Figure 7 and the section on Seedbed Preparation for a complete description of contour ripping. Some basic design considerations include:

1. The rips should be approximately 8-12 inches deep or to the depth of topsoil.

2. Ripping should be on the contour, with a gradient not to exceed two percent.

3. Excavation of each rip should be in the opposite direction from the preceding one to minimize build-up of loose material at the ends of rips.

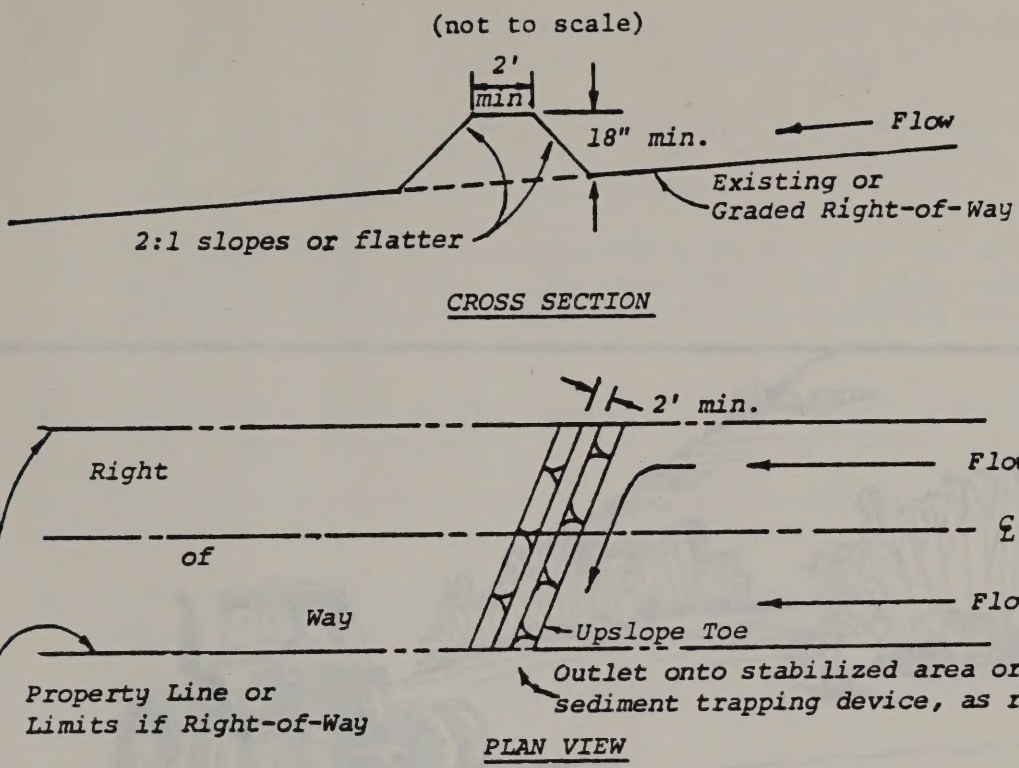
4. Loose material which collects at the ends should be removed and ends blended into the natural ground.

Channel Liners and Energy Dissipators.

Construction Specifications for a paved chute or flume included:

1. The structure should be placed on undisturbed soil or on

Figure 6. Example of construction specifications for waterbars as outlined by USDA (USDA Soil Con. Serv. 1975).



Construction Specifications

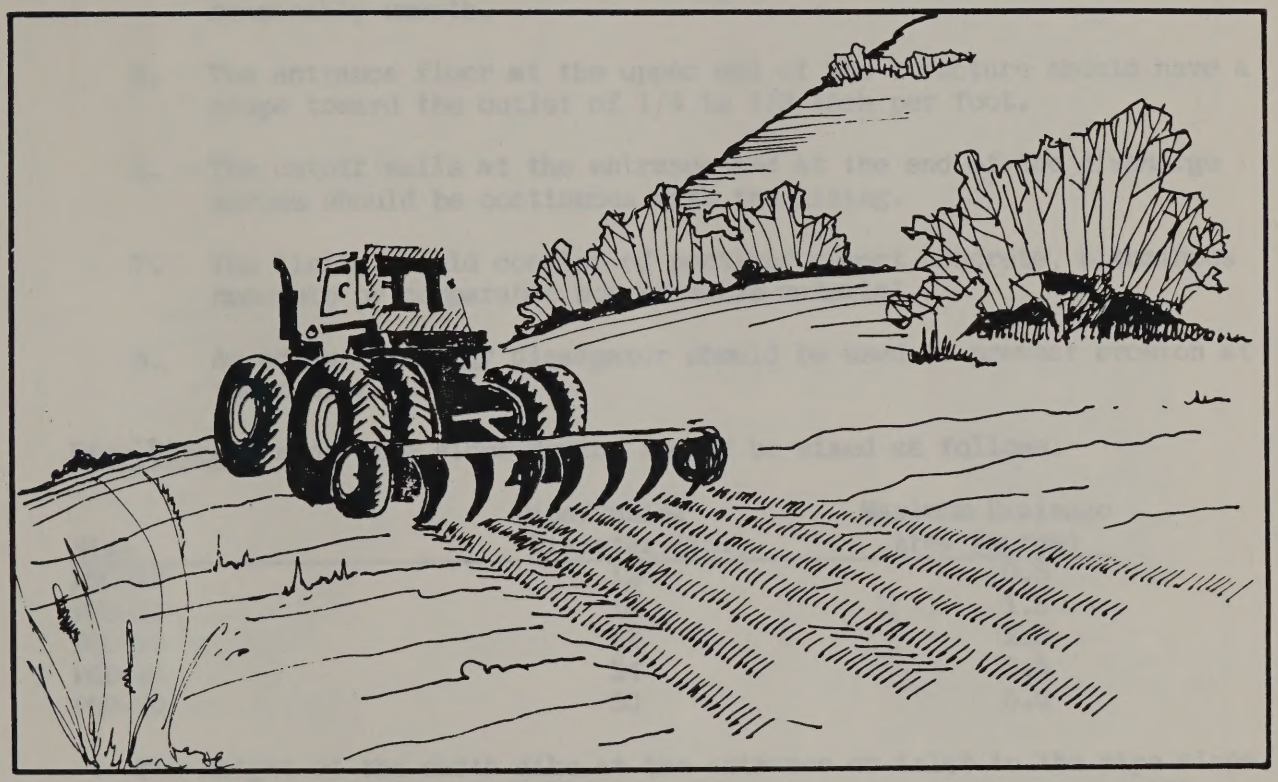
1. All dikes shall be machine compacted.
2. All interceptor dikes shall have positive drainage to an outlet.
3. Top width may be wider and side slopes may be flatter if desired to facilitate crossing by construction traffic.
4. Field location should be adjusted as needed to utilize a stabilized safe outlet.
5. Interceptor dikes shall have an outlet that functions with a minimum of erosion. Runoff shall be conveyed to a sediment trapping device such as a sediment trap or sediment basin when either the interceptor dike channel or the drainage area above the dike are not adequately stabilized.
6. Stabilization, as specified by the plans, shall be: (1) in accordance with Standard and Specifications for Grassed Waterway, and the area to be stabilized shall be the channel (flow area); or (2) the flow area shall be lined with stone that meets MSHA size No. 2 or AASHTO size No. 2 or 24 which is placed in a 3 inch thick layer and pressed into the soil. The area covered by the stone shall be as shown on Standard Drawing DD-1.
7. Periodic inspection and required maintenance must be provided.

* Drainage area less than 5 acres. Standard Symbol ID

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE College Park, Md.		



Figure 7. Example of contour ripping.





well-compacted fill.

2. The cut or fill slope should not be steeper than 1.5 horizontal to 1 vertical (1.5:1) and should not be flatter than 20:1.

3. The top of the earth dike at the entrance and those dikes carrying water to it should not be lower at any point than the top of the lining at the entrance of the structure.

4. The lining should be placed beginning at the lower end and proceeding up the slope to the upper end. The lining should be well compacted, free of voids, and the lining surface should be reasonably smooth.

5. The entrance floor at the upper end of the structure should have a slope toward the outlet of 1/4 to 1/2 inch per foot.

6. The cutoff walls at the entrance and at the end of the discharge aprons should be continuous with the lining.

7. The lining should consist of portland cement concrete, bituminous concrete or comparable non-erodible material.

8. An adequate energy dissipator should be used to prevent erosion at the outlet.

Pipe Slope Drain. Pipe slope drains should be sized as follows:

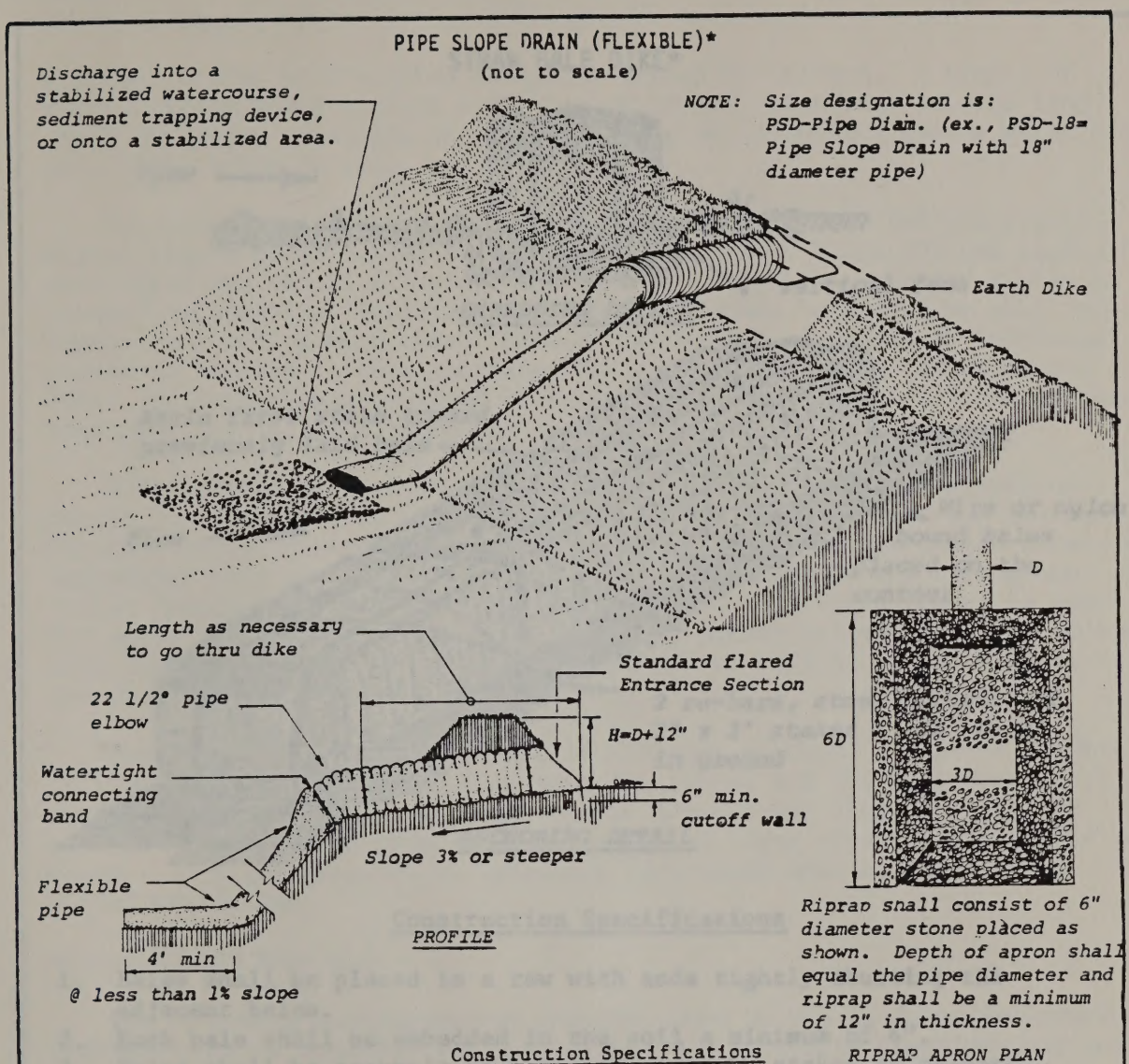
Size	Pipe/Tubing Diameter (in.)	Maximum Drainage Area (acres)
PSD-12	12	0.5
PSD-18	18	1.5
PSD-21	21	2.5
PSD-24	24	3.5
PSD-30	30	5.0

The height of the earth dike at the entrance or inlet to the pipe slope drain should be equal to or greater than the diameter of the pipe + 12" (Figure 8).

The pipe slope drain should outlet onto a riprap apron and then into a stabilized area or stable watercourse. A sediment trapping device should be used to trap sediment from any sediment laden water conveyed by the pipe slope drain. Sufficient drainage should be allowed so that moisture build-up in the drain does not occur, making it susceptible to freezing.

Straw Bale Dike. All bales should be placed on the contour and should be either wire bound or nylon string tied. Bales should be placed in a row with ends tightly abutting the adjacent bales. Each bale should be embedded in the soil a minimum of 4" (Figure 9). Bales should be securely anchored in place by stakes or re-bars driven through the bales. The first stake in each bale should be driven toward previously laid bale to force bales together. Due to the short life of the bales, inspection should be frequent and repair or replacement should be made promptly as needed.

Figure 8. Example of construction specifications for pipe slope drain as outlined by USDA (USDA Soil Con. Serv. 1975).



Construction Specifications

1. The inlet pipe shall have a slope of 3% or steeper.
2. The top of the earth dike over the inlet pipe and those dikes carrying water to the pipe shall be at least 1' higher at all points than the top of the inlet pipe.
3. The inlet pipe shall be corrugated metal pipe with watertight connecting bands.
4. The flexible tubing shall be the same diameter as the inlet pipe and shall be constructed of a durable material with hold-down grommets spaced 10' on centers.
5. The flexible tubing shall be securely fastened to the corrugated metal pipe with metal strapping or watertight connecting collars.
6. The flexible tubing shall be securely anchored to the slope by staking at the grommets provided.
7. A riprap apron shall be provided at the outlet. This shall consist of 6" diameter stone placed as shown on Standard Drawing GSS-3.
8. The soil around and under the inlet pipe and entrance section shall be hand tamped in 4" lifts to the top of the earth dike.
9. Follow-up inspection and any needed maintenance shall be performed after each storm.

* Drainage area must not exceed 5 acres.

Standard Symbol GSS-3
PSD-diam.

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE College Park, Md.	GRADE STABILIZATION STRUCTURE	

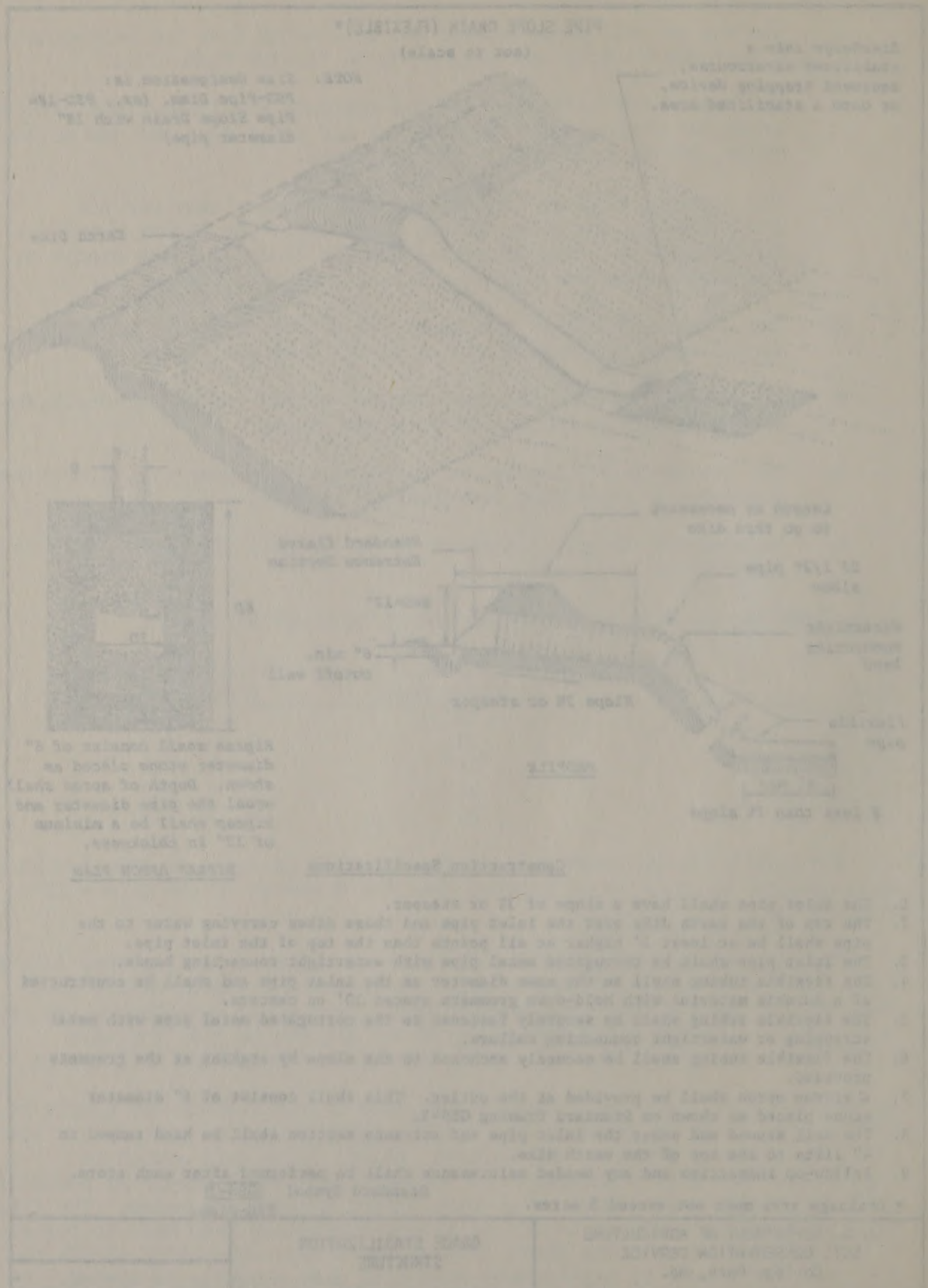
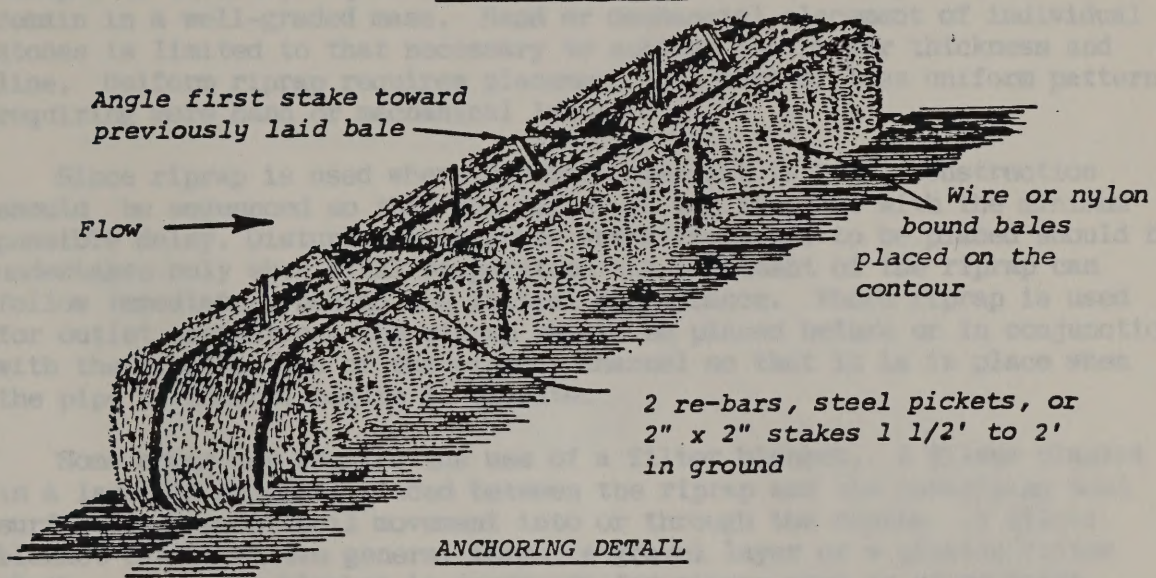


Figure 9. Example of construction specifications for straw bale dike as outlined by USDA (USDA Soil Con. Serv. 1975).

STRAW BALE DIKE*



EMBEDDING DETAIL



ANCHORING DETAIL

Construction Specifications

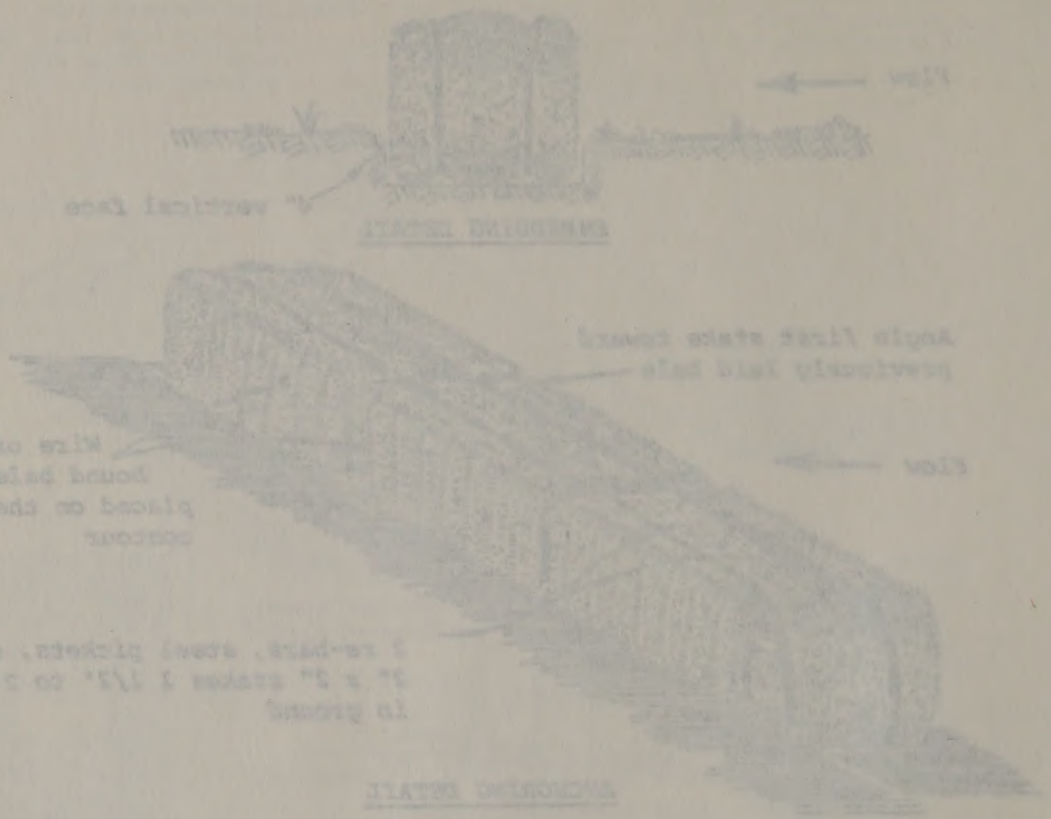
1. Bales shall be placed in a row with ends tightly abutting the adjacent bales.
2. Each bale shall be embedded in the soil a minimum of 4".
3. Bales shall be securely anchored in place by stakes or re-bars driven through the bales. The first stake in each bale shall be angled toward previously laid bale to force bales together.
4. Inspection shall be frequent and repair or replacement shall be made promptly as needed.
5. Bales shall be removed when they have served their usefulness so as not to block or impede storm flow or drainage.

Standard Symbol — SBD

* Drainage area less than 1/2 acre.

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE College Park, Md.	STRAW BALE DIKE	

STRAW BALE DIKE*



	STRAW BALE DIKE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE College Park, MD.

Bales should be removed when they have served their usefulness so as not to block or impede storm flow or drainage.

Riprap. Riprap is classifed as either graded or uniform. A sample of graded riprap would contain a mixture of stones which vary in size from small to large. A sample of uniform riprap would contain stones which are all fairly close in size.

For most applications, graded riprap is preferred to uniform riprap. Graded riprap forms a flexible, self-healing cover, while uniform riprap is more rigid and cannot withstand movement of the stones. Graded riprap is cheaper to install, requiring only that the stones be dumped so that they remain in a well-graded mass. Hand or mechancial placement of individual stones is limited to that necessary to achieve the proper thickness and line. Uniform riprap requires placement in a more or less uniform pattern, requiring more hand or mechanical labor.

Since riprap is used where erosion potential is high, construction should be sequenced so that the riprap is put in place with the minimum possible delay. Disturbance of areas where riprap is to be placed should be undertaken only when final preparation and placement of the riprap can follow immediately behind the initial disturbance. Where riprap is used for outlet protection, the riprap should be placed before or in conjunction with the construction of the pipe or channel so that it is in place when the pipe or channel begins to operate.

Some areas may require the use of a filter blanket. A filter blanket is a layer of material placed between the riprap and the underlying soil surface to prevent soil movement into or through the riprap. A filter blanket can be of two general forms: a gravel layer or a plastic filter cloth. No filter blanket is necessary for riprap used as storm drain outlet protection.

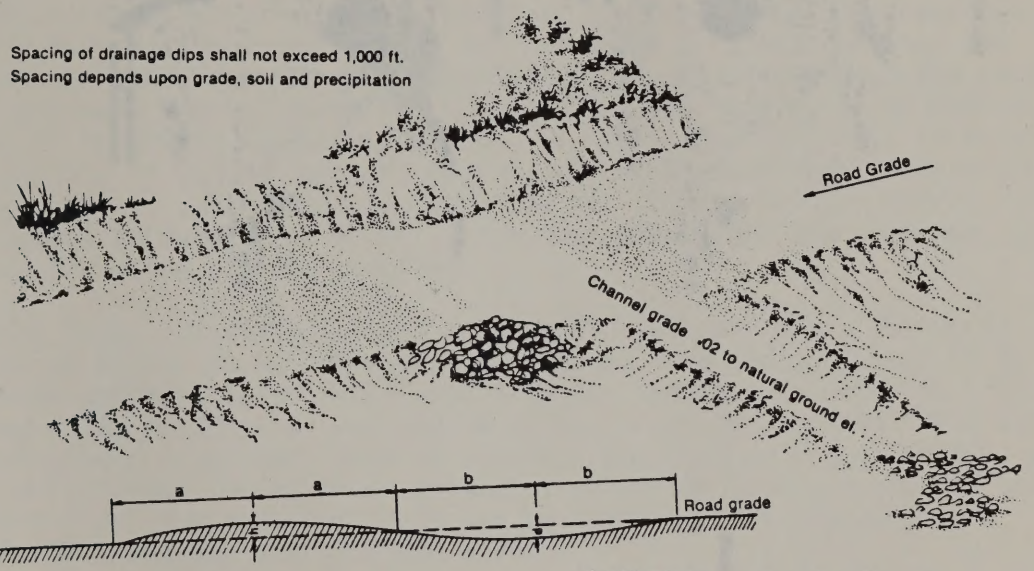
Miscellaneous Practices

The following techniques are included here to aid in designing erosion sediment control measures for a site when the foregoing practices are not adequate or practical.

Drainage Dip. A drainage dip is a temporary or permanent structure constructed across a graded right-of-way and is designed to reduce erosion by intercepting storm runoff and diverting it where it can be disposed of with minimal erosion. They are broad and shallow and are designed to allow vehicles to pass over them during and after construction activities (Figure 10).

Culverts. A culvert is a conduit used to provide free passage of surface drainage water under a highway, canal or other embankment. Typical placement of a culvert is shown in Figure 11. The conduits are usually constructed of corrugated metal or reinforced concrete pipes. Opentop culverts consisting of box-like frames installed flush with the road surface are used on very low-traffic, unpaved roads. Design considerations are not included here but if needed the reader shoulded refer to "California Culvert Practice" published by the California Division of

Figure 10. Schematic of a drainage dip designed to transfer water across a road without slowing traffic appreciably (USDA BLM 1977).

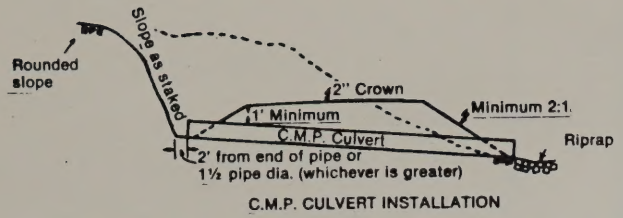


NOTE: All waterbreak material shall be taken from the waterbreak dip or from the ditch line.

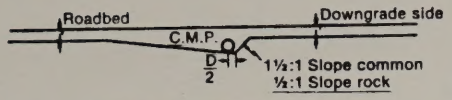
Road Gradient	d	h	a	b
2%	0.6'	0.4'	10'	10'
4%	1.0'	0.8'	14'	14'
6%	1.2'	1.4'	16'	18'
8%	2.0'	2.2'	22;	24'

CROSS SECTION OF WATERBREAK

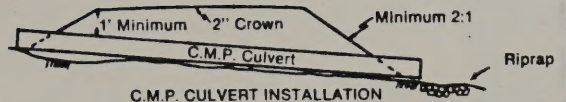




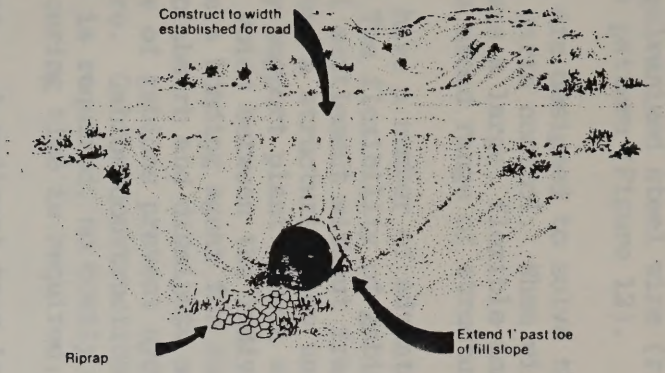
C.M.P. CULVERT INSTALLATION



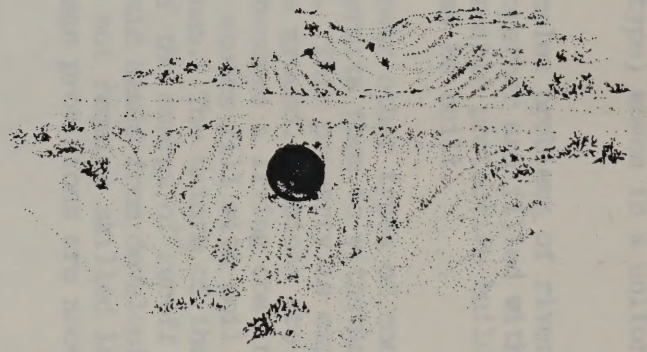
DITCH CONSTRUCTION AT SIDE HILL
C.M.P. CULVERT INSTALLATION



C.M.P. CULVERT INSTALLATION
EMBANKMENT SECTION



ACCEPTABLE



NOT ACCEPTABLE

General Notes:
1. In bedding of C.M.P. Culverts, if the foundation is rock, excavate to depth of 8 in. below culvert grade and replace with earth cushion.
2. Minimum cover over culvert is one foot (1').
3. Minimum culvert diameter 18".
4. Minimum culvert spacing:
   (a) 1- 2% grade — 1000 feet minimum
   (b) 2- 4% grade — 800 feet minimum
   (c) 4- 6% grade — 600 feet minimum
   (d) 6- 8% grade — 400 feet minimum
   (e) 8-10% grade — 250 feet minimum
5. Maximum grade 10%.

Figure 11. Diagram showing proper installation of culverts (USDA BLM 1977).

Highways, (1978).

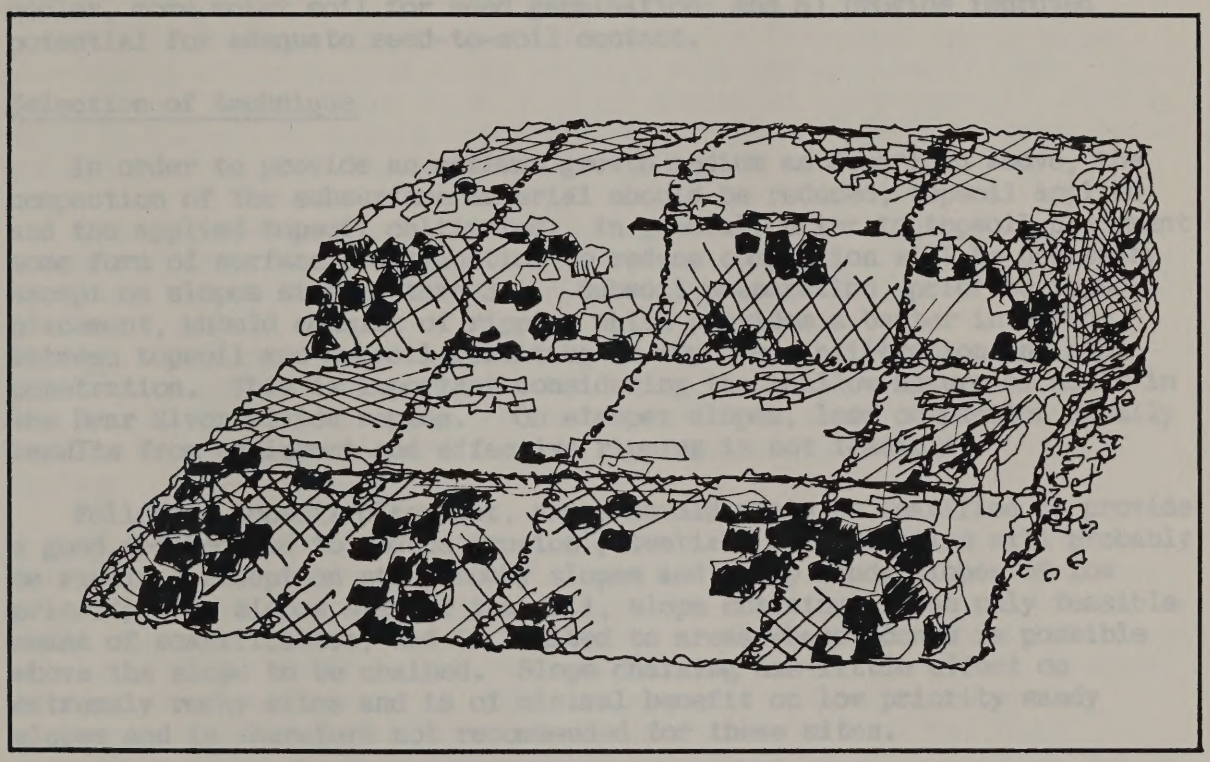
Gabions. Gabions are compartmented rectangular rock-filled containers made of heavily galvanized steel wire (river type) woven in a uniform hexagonal triple-twist pattern (Figure 12).

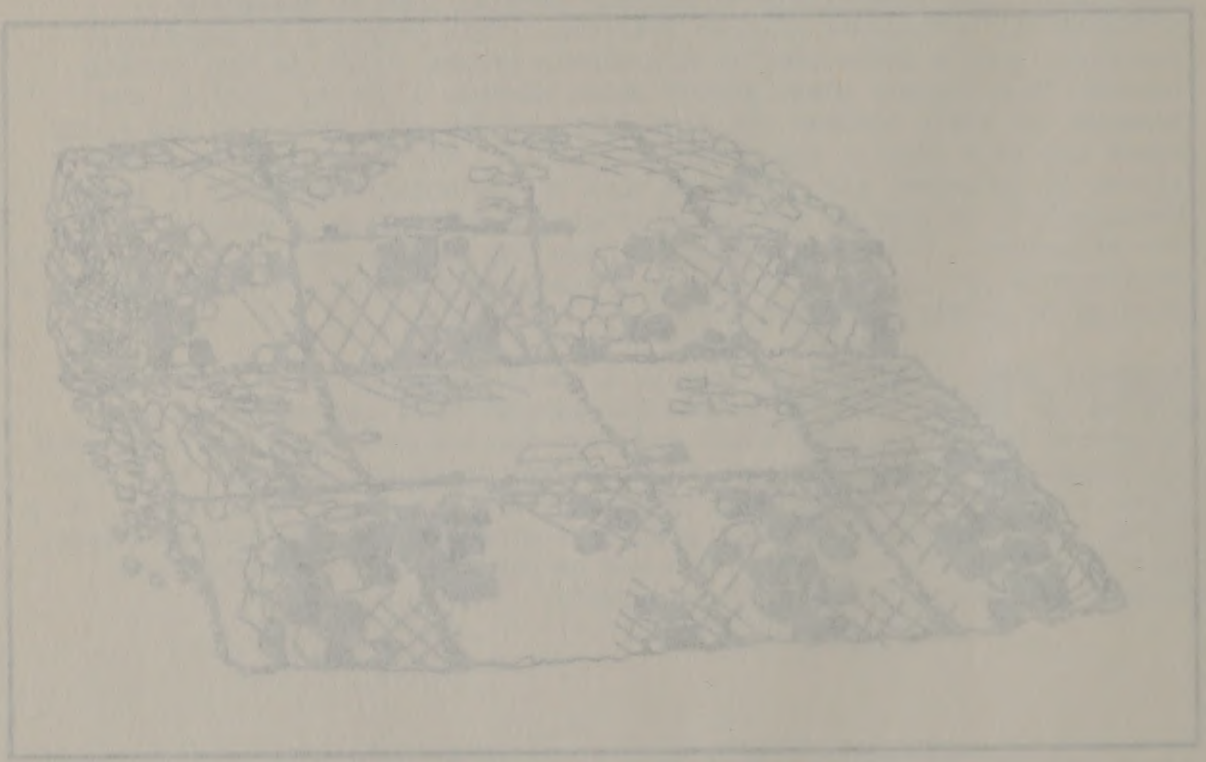
Gabions are designed to solve the complex problems of river bank erosion and earth control. When wired together and filled with stone, the gabion becomes a large, flexible and permeable protective building block from which a broad range of structures may be built.

Gabions have a number of advantages over other types of construction materials. The flexibility of gabions permits them to withstand differential settlement without fracture. This property is especially important when a structure is on unstable ground. Gabions are durable because they support plant growth which becomes a living coating, and because the voids between the individual stones fill with soil and roots which act as a bonding agent for the stones. The nature of the gabion allows it to absorb and dissipate much of the energy of runoff by water. Permeability of gabions prevent hydrostatic heads from developing behind the structure. Gabion construction does not require skilled labor. Little maintenance is required, no costly drainage provisions are necessary and no forming or curing time is required.

Sediment Trap. A sediment trap is a small temporary basin formed by excavation and/or an embankment. The purpose of a sediment trap is to intercept sediment laden runoff and trap the sediment in order to protect drainageways, properties, and rights-of-way below the sediment trap from sedimentation. A sediment trap is usually installed in a drainageway, at a storm drain inlet, or at other points of discharge from a disturbed area. Specifications for sediment traps can be found in Salt Lake County's Erosion Sediment Control Handbook (1981).

Figure 12. Example of a gabion.





SEEDBED PREPARATION

The ideal seedbed for direct seeding has been defined by Vallentine (1980) as being: 1) very firm below seeding depth; 2) well pulverized and friable on top; 3) not cloddy nor puddled; 4) free from live resident plant competition; 5) free from seed of competitive species; and 6) containing moderate amounts of mulch or dead plant material on the soil surface. Many areas lack some of these desirable characteristics and require modification through preparation of the plant growth medium. Seedbed preparation consists of primary and secondary tillage (cultivation) practices designed to: 1) provide soil aeration; 2) provide erosion control and increase water infiltration; 3) reduce excessive soil compaction; 4) provide a looser, cooler, more moist soil for seed germination; and 5) provide improved potential for adequate seed-to-soil contact.

Selection of technique

In order to provide an optimum growth medium as described above, the compaction of the subsurface material should be reduced, topsoil applied and the applied topsoil cultivated. In general, prior to topsoil placement some form of surface scarification to reduce compaction will be necessary except on slopes steeper than 3:1. Subsoil preparation, prior to topsoil placement, should consist of ripping which provides a better interface between topsoil and subsoil resulting in improved infiltration and root penetration. This is important considering the shallow nature of soils in the Bear River Divide region. On steeper slopes, less compaction usually results from equipment and effective ripping is not feasible.

Following topsoil placement, areas should again be scarified to provide a good seedbed and to reduce erosion potential. Scarification will probably be required except on steep rocky slopes and steep sandy slopes of low priority. On slopes steeper than 3:1, slope chaining is the only feasible means of scarification, and is limited to areas where access is possible above the slope to be chained. Slope chaining has little effect on extremely rocky sites and is of minimal benefit on low priority sandy slopes and is therefore not recommended for these sites.

Following topsoil replacement, nonrocky or accessible sites can either be ripped (or chiseled) or disked. Ripping (or chiseling) is more effective than disking on rocky sites. When preparing a rocky site, discs are more susceptible to breakage. Ripping is also more effective on more compacted areas. Care should be taken when ripping or disking not to bring undesired subsurface material to the surface.

If the primary tillage of the topsoil has resulted in an extreme cloddy surface, then secondary tillage will be necessary to optimize seed coverage. Secondary tillage consists of disking or harrowing. This may be necessary following primary tillage during the spring since clods have not had a chance to breakdown during the winter. Tillage should be completed during the fall when possible since spring tillage causes more rapid drying of the soil surface. The avoidance of excessive clods should not be confused with a "roughened" seedbed. A roughened seedbed is desirable particularly with broadcast seeding, because it provides many microelevation changes and thus, varied microhabitats for diverse

vegetation establishment.

Site Preparation Techniques

Ripping. Ripping of sites prior to topsoil placement can be accomplished by pulling shanks through the subsoil to a depth of 12-18 inches. Following topsoil replacement ripping should be limited to the depth of the topsoil up to a maximum of 12 inches. Deeper ripping on pads is required due to the greater compaction. Ripping can be accomplished by using subsoilers. Subsoilers generally consist of stout shanks attached solidly to a toolbar, frame or special hitch and can be raised or lowered hydraulically.

Chisel plows can also be used to a depth of 12 inches. Chisel plows have curved shanks mounted along toolbars with spring-loaded clamps. The spring clamp enables each shank to clear obstacles independently. Plowing depth is controlled hydraulically. The chisel plow prepares an excellent seedbed for broadcast seeding.

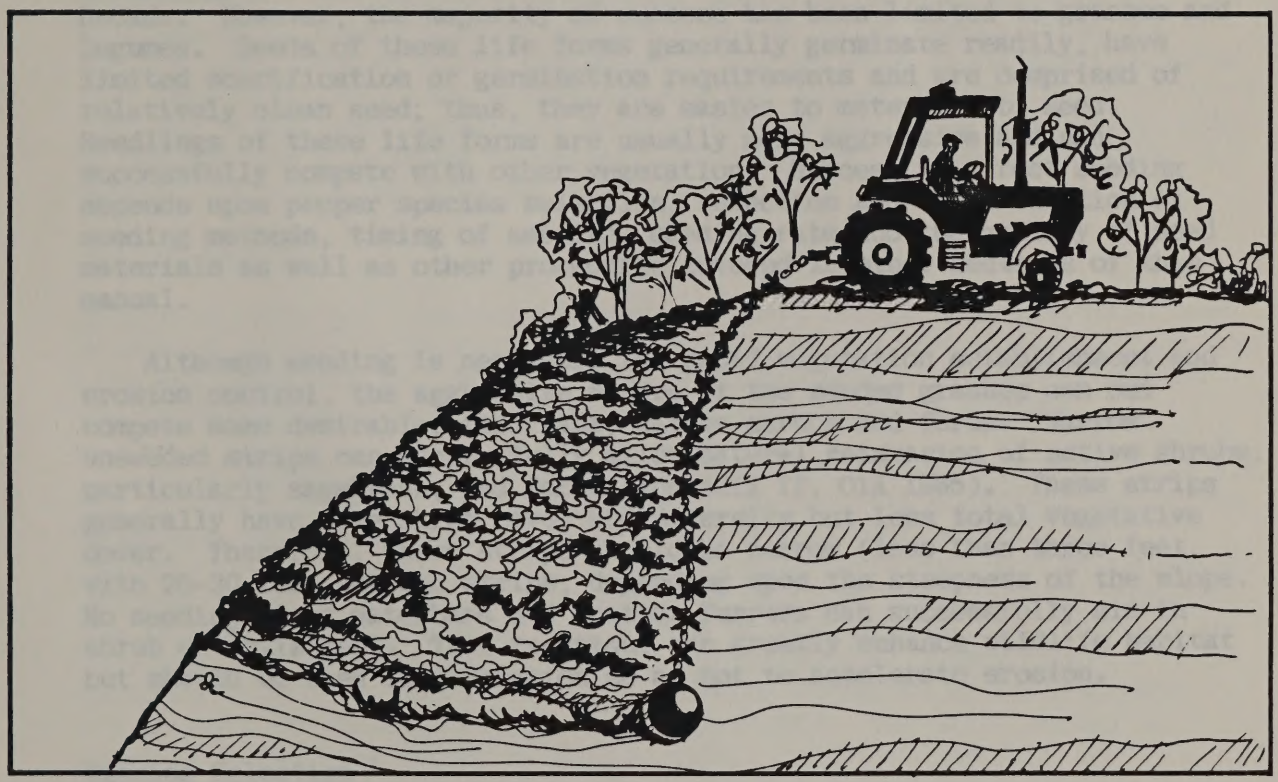
Ripping is more effective on relatively dry soils to permit shattering of the compacted layer. When ripping wet soils, a thin slot is created which may reseal quickly. Sites should be ripped on the contour.

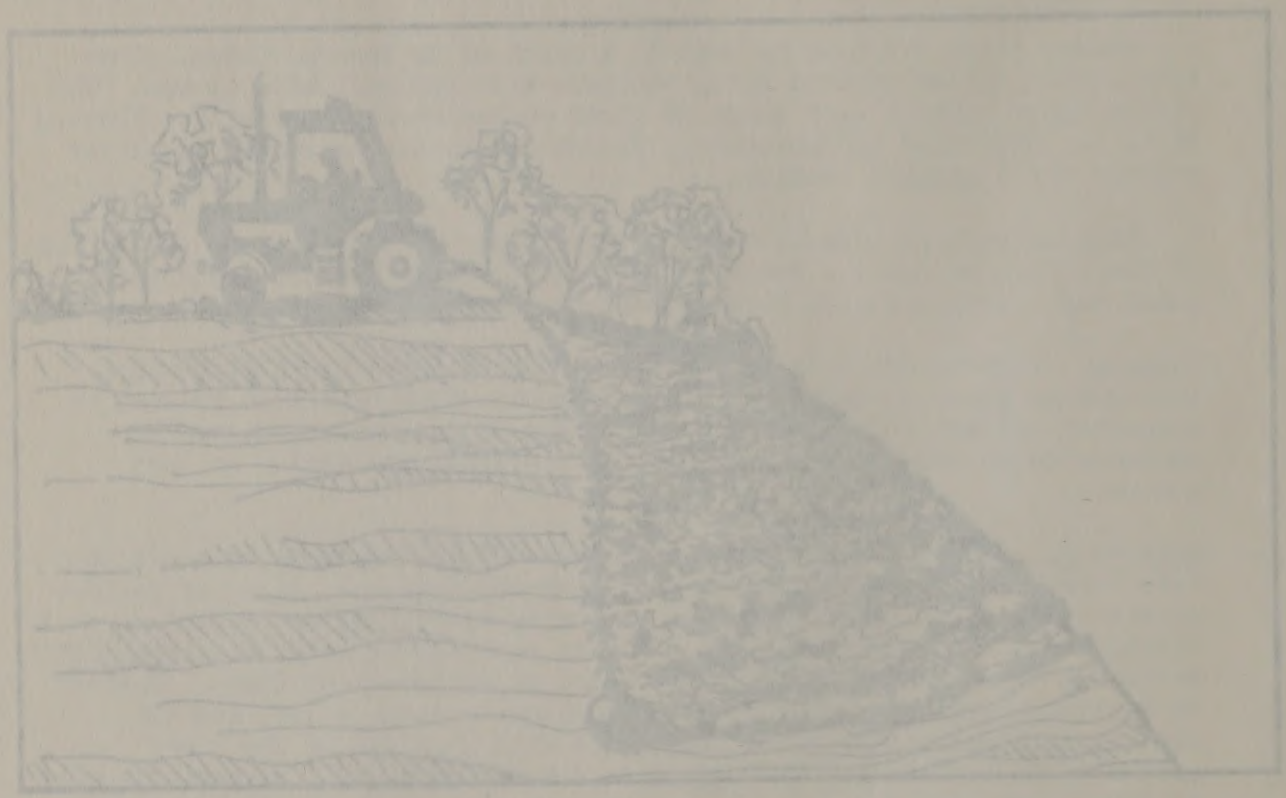
Disking. Disking of replaced topsoil is accomplished by pulling disks attached to gangs to the depth of the topsoil. Disking should be used as secondary tillage if ripping has left large clods. Disking should be implemented on relatively dry soils. Sites should be disked on the contour.

Harrowing. Harrows are used for secondary tillage to break up clods that have formed from ripping. Harrows can consist of disks, tines or various scarifying tips attached to gangs. Harrowing is not very effective on rocky sites. Spring harrows or field cultivars are more durable than spike tooth harrows. They resemble light-duty chisel plows described above. Blanket or English meadow harrows are better adapted to rough sites, and are similar to a section of chain link fence with the ends of the links extending at various depths to provide scarifying edges. Harrowing should be done on the contour.

Slope Chaining. Slope chaining, sometimes called clod busting, prepares steep slopes for seeding where access above the slope is possible (Figure 13). The slope chain consists of a length of lead chain connected to a truck or tractor, various lengths of scarifying chains depending on the length of slope, and a slope wheel, connected by swivels. Pairs of 6-inch steel picks or other scarifying devices are welded to the scarifying chain at right angles. The slope wheel has a heavy (500 lb.) weight attached. The lead chain is attached to a tractor operating on a road or bench above the slope. The chain is dragged across the slope. Several passes are usually necessary. Slope chaining is not very effective on very rocky or very compact sites.

Figure 13. Example of slope chaining.





SEEDING

The reestablishment of vegetation for erosion control and wildlife habitat establishment is expedited through direct seeding. Although disturbances should be minimized thus increasing the rate of natural colonization from the edge of disturbance, and topsoil should be salvaged and replaced as quickly as possible thus contributing a source of plant and seed materials, these techniques by themselves are insufficient to establish rapid vegetation cover and therefore require augmentation by direct seeding. Considerable progress has been made in direct seeding technology for disturbed sites in the arid and semiarid west in the past decade. However, the majority of success has been limited to grasses and legumes. Seeds of these life forms generally germinate readily, have limited scarification or germination requirements and are comprised of relatively clean seed; thus, they are easier to meter and to seed. Seedlings of these life forms are usually more aggressive and can successfully compete with other vegetation. Success in direct seeding depends upon proper species selection, selection and implementation of seeding methods, timing of seeding, seeding rate and the quality of seed materials as well as other procedures covered in other sections of this manual.

Although seeding is necessary for rapid vegetation establishment and erosion control, the aggressive nature of the seeded grasses can out compete some desirable, important, native shrubs and forbs. Narrow unseeded strips can successfully allow natural reinvasion of native shrubs, particularly sagebrush, and forbs (Appendix II, OIA 1985). These strips generally have more shrub cover and diversity but less total vegetative cover. Therefore, these strips should be narrow (less than three feet, with 20-30 feet between strips, depending upon the steepness of the slope. No seeding along waterbars and contour furrows can successfully aid in shrub establishment. This technique can greatly enhance wildlife habitat but should be used in moderation so as not to accelerate erosion.

Species Selection

Selection and use of plant species for disturbed land revegetation depends upon an integrated consideration of four basic factors:

1) species adaptation
2) species germination and establishment requirements
3) species functional utility for land use goals
4) species availability

The selection and use of species in ignorance of one or more of the above factors may lead to inadequate revegetation success or complete revegetation failure. Proper selection of species is as important to successful reclamation as is subsequent use of proper establishment and management practices.

Because of the importance of species selection, a primary goal of the field survey (Appendix II, OIA 1985) was to identify those species that were performing well on the disturbed sites. These include those species

that were seeded as well as those that were invading naturally from the surrounding vegetation and that could be used for future revegetation. This information was combined with information from various sources regarding the four factors listed above to arrive at recommended species lists for the three major moisture/vegetation categories identified in the reclamation matrix (see Tables 3-5). It is important to point out that these are recommendations for the Bear River Divide and adjacent areas and that site specific refinements for particular soils types, etc. may be useful. The list of substitute species in Tables 3-5 should be used when site conditions are appropriate. The mixes are primarily designed for erosion control/site stability which is the short-term objective for most of the sites but must be met if the long-term objective is to be accomplished. The long-term objective, establishing wildlife habitat, can be enhanced or accelerated by utilizing the wildlife augmentation mix (Tables 3-5). The wildlife augmentation mix would be recommended on sites that have relatively flat slopes and are not subject to erosion or on sites that are of critical importance to wildlife. These mixes can also be used in conjunction with other techniques described in this manual designed to enhance the reclaimed area for wildlife.

Seeding Methods

Selection Criteria. Seeding methods have been categorized into drill and broadcast seeding categories. The selection of the method depends upon the site accessibility and terrain, seedbed characteristics, time of seeding, and characteristics and variability of species within a mixture.

Drill seeding is limited to slopes of 3:1 or flatter and areas that are not extremely rocky. The rangeland drill or specific modifications of the rangeland drill (e.g. Truax) is often the most effective drill for reclamation drill seeding. It is a heavy-duty drill with a high clearance, reinforced frame, and disk furrow openers that are independently suspended. The furrows are covered with drag chains or pipe drags. The disks can be equipped with different sized depth bands to control furrow depth. Multiple seed boxes can be used for metering different sized seeds and attachments can be used for applying fertilizer. The drill should be capable of handling fluffy or trashy seed.

Drill seeding improves seed coverage, allows reduced seeding rates, accurate seed metering and calibration and can be used to seed into stubble mulch or preexisting vegetation. Drill seeding does leave rows which may be aesthetically unappealing and can result in increased competition from the concentration of seeds in the row. Drill seeding may result in some extremely small seed being planted too deep. The optimum seeding depth sometimes varies widely among plant species, with larger seeded species often requiring deeper planting depth. Drill seeding places the seeds of all species at the same depth, thus favoring some species, particularly large seeded species such as grasses, and usually resulting in a less diverse stand of vegetation than one established from broadcast seeding. This can be partially alleviated by placing smaller seeds in different seed boxes and alternating the seeding depth between rows.

Broadcast seeding is generally required on slopes steeper than 3:1, on extremely rocky sites or on remote or inaccessible sites, where seed is

Table 3. Recommended species for seeding in the dry vegetation types. Also included is a wildlife augmentation mix and other species that could be substituted if recommended species are unavailable.

Species	Recommend Rate (based on drill seeding rate of 15 PLS lbs/acre)
Siberian wheatgrass	2.0
western wheatgrass (Rosana or arriba)	2.0
Indian ricegrass	2.0
thickspike wheatgrass	1.0
Russian wildrye	2.0
Gardner saltbush	3.0
pubescent wheatgrass	1.0
alfalfa (Ranger)	1.0
Utah sweetvetch	1.0
Wildlife augmentation mix	
shadescale	1.0
small burnett	2.0
prostrate summer cyprus	1.0
Wyoming sagebrush (palatable variety as available)	1.0
winterfat	2.0
Lewis flax	1.0

Species that could be substituted as site conditions require

bluebunch wheatgrass (substitute for wheatgrass)
yellow sweet clover (substitute for Utah sweetvetch)
alkali sacaton (use on sodic sites)
crested wheatgrass (substitute for Siberian wheatgrass)
squirreltail (use on extremely harsh sites)
Nuttall saltbrush (substitute for Gardner saltbush)
Lewis flax

Table 4. Recommended species for seeding in the intermediate vegetation types. Also included is a wildlife augmentation mix and other species that could be substituted if recommended species are unavailable.

Species	Recommend Rates (based on drill seeding rate of 15 PLS lbs/acre)
western wheatgrass (Rosana or Arriba)	3.0
intermediate wheatgrass	2.0
thickspike wheatgrass	2.0
slender wheatgrass	2.0
basin wildrye	2.0
Columbia needlegrass	1.0
sainfoin	1.0
alfalfa	0.5
cicer milkvetch	0.5
sheep fescue (covar)	1.5
Wildlife augmentation mix	
yarrow	0.5
winterfat	1.0
Wyoming sagebrush (palatable variety as available)	1.0
bitterbrush	2.0
serviceberry	2.0
Utah sweetvetch	0.5
Palmer penstemon	0.5
Species that could be substituted as site conditions require	
mutton bluegrass (substitute for Columbia needlegrass)	
Streambank wheatgrass (substitute for wheatgrass)	
yellowsweet clover (substitute for legume)	
Indian ricegrass (use or sandy sites)	
Siberian wheatgrass (substitute for wheatgrasses)	
pubescent wheatgrass (substitute for wheatgrasses)	
green needlegrass (substitute for Columbia needlegrasses)	
bluebunch wheatgrass (substitute for wheatgrass)	
sulfur buckwheat (substitute for penstemon)	
balsamroot (substitute for penstemon)	
Lewis flax (substitute for yarrow)	

Table 5. Recommended species for seeding in the moist vegetation types. Also included is a wildlife augmentation mix and other species that could be substituted if recommended species are unavailable.

Species	Recommend Rates (based on drill seeding rate of 15 PLS lbs/acre)
slender wheatgrass	3.0
mountain brome	2.5
intermediate wheatgrass	2.0
Kentucky bluegrass	2.0
hard sheep fescue	1.0
Columbia needlegrass	1.0
pubescent wheatgrass	2.0
cicer milkvetch	0.5
Utah sweetvetch	0.5
sainfoin	0.5
Wildlife augmentation mix	
Rocky mountain penstemon (Bandera)	0.5
woods rose	1.0
snowberry	1.0
serviceberry	2.0
bitterbrush	2.0
wild geranium	0.5
yarrow	0.5
Species that could be substituted as site conditions require	
thickspike wheatgrass (substitute for mountain brome on steep slopes)	
bluebunch wheatgrass (substitute for wheatgrass)	
smooth brome (substitute for mountain brome)	
orchard grass (substitute for Columbia needlgrass)	
timothy (substitute for Columbia needlegrass)	
green needlegrass (substitute for Columbia needlegrass)	
mutton bluegrass (substitute for hard fescue)	
birdsfoot trefoil (substitute for cicer milkvetch)	
sheep fescue (substitute for penstemon)	
balsamroot (substitute for penstemon)	
sulfur buckwheat (substitute for penstemon)	
Lewis flax (substitute for geranium)	

small in size or trashy and in areas where drill rows are undesirable. Broadcast seeding does require raking, chaining, harrowing or cultipacking to ensure seed coverage where possible. Broadcasting normally requires heavier seeding rates and results in less efficient use of the seed. It is difficult to calibrate seeding rates precisely. Germination and seedling establishment are somewhat slower although diversity is higher than drill seeded areas. Broadcasting into a rough seedbed, followed by harrowing or cultipacking results in a variable range of seed depths for seed placement in the soil and allows for better establishment from small seeds such as sagebrush.

The benefits of broadcast and drill seeding may be obtained through a combination of the two methods by using a seeder/cultipacker such as the 'Brillion' seeder. This basically consists of a seedbox mounted above and between tandem cultipackers consisting of metal wheels with a shallow groove around the perimeter. The first roller firms the seedbed and makes shallow grooves. The second roller splits the ridges left by the front roller, covers the seed and presses soil around it. The Brillion seeder can be used instead of the rangeland drill on well-prepared topsoiled areas where the surface is relatively free of rocks.

Hydroseeding is a modified form of broadcast seeding that involves using a pressurized spray of water containing seeds and other materials such as mulch and fertilizer. Seed can become damaged from the mechanical action of the hydroseeder. Hydroseeding is fairly expensive and is dependent on local water supplies. In the Bear River Divide region, hydroseeding should be limited to steep, inaccessible slopes.

Description of Techniques. Seeding equipment must be calibrated so that proper quantitites of seed are dispersed per unit area. The drill seeder owner's manual ussally gives the opening setting for presetting the desired rate. However, because of field conditions and seed size, the drill should be calibrated again in the field. The most common way to calibrate seed flow is to put enough seed in the drill to seed one or two acres and then check the amount of seed used with the acre meter on the drill and adjust accordingly. Broadcast seedings should be calibrated by measuring one acre and spreading the specified amount of seed. Seeders can occasionally become clogged, particularly when seeding the more trashy or fluffy seed like the wildlife augmentation mix. Therefore, the seeder must be continually monitored for stoppage or uneven dispersion.

Drill seeding depths should be set at 1/4 to 3/4 inch deep for most grasses. Larger seeds can be placed deeper than smaller seed. The basic mixes in this manual should be seeded at a depth of 1/2 inch. Winterfat does not need to be covered.

All drill seeding should be done on the contour to avoid water flowing down drill rows. Broadcast seed should be raked, harrowed or cultipacked on the contour. Broadcast seeding should be avoided on windy days. Care should be taken to ensure uniform coverage of an area. Excessive seed will be wasted and spotty coverage results in bare areas susceptible to erosion.

To minimize seed damage while hydroseeding, a small amount of fiber mulch (200-400 lbs./acre) should be added to the water and seed slurry to

act as a buffer. Fiber mulch also has a green dye which provides the operator with a guide in applying an even application of seed. Large quantities of fiber mulch should not be applied with the seed because the fibers prevent good seed-to-ground contact and upon drying a thick layer of fiber may shrink and pull the young seedlings from the ground.

Some fluffy seed such as winterfat may require additional mixing and wetting in order to be seeded. However, the water and seed slurry should be applied within two hours, otherwise seed coats will become too soft and damage to seeds may occur.

Fertilizer should not be added to the hydroseed mixture as the high concentration of salts from the fertilizer can damage the seed.

Timing. Seeding of disturbed areas should begin during the first available seeding "window". Two seeding windows exist in the Bear River Divide area. The fall seeding window generally runs from September until winter conditions preclude further seeding usually by November. During the fall, higher elevations should be seeded first. The spring seeding window starts at the earliest time that access is possible; April at lower elevations to May at higher elevations and extends for approximately 2-4 weeks or until June. During the spring, lower elevations should be seeded first. Since these windows are narrow, site preparation should be completed shortly before the window begins, thus allowing the maximum amount of time possible for seeding. Areas to be seeded during the spring should be prepared during the fall if possible. Contracts should be let and seed materials ordered well in advance in order to ensure prompt start-up of seeding operations.

Of the two seeding windows, fall seeding carries less of a risk than spring seeding. As much area as possible should be planned for seeding during the fall. Fall seeding allows utilization of moisture recharge during the winter. By the time conditions are dry enough to allow access for spring seeding, part of the moisture build-up has been lost. Site preparation during the spring will also dry out sites quicker. Some shrub species require winter stratification for germination. Cicer milkvetch has an extremely hard seed coat and seems to establish more readily from fall seedings. Winterfat seems to establish more readily if seeded prior to a snowstorm and if the area does not dry out before spring.

The timing of seedings can be used to some degree to manipulate the species composition of the revegetation. Grass seeds generally germinate more quickly and seedlings establish more readily than shrub and tree seedlings. The competition from grass seedlings may limit or prohibit establishment of shrub seedlings. On flatter areas where erosion control is not a major problem, the wildlife augmentation mix could be sown one growing season prior to the basic seed mix to enable the wildlife mixture to become better established.

It is important to revegetate disturbances as soon as possible during the first available seeding window following site preparation. The longer the time period between seedbed preparation and seeding, the more suceptible the area is to surface crusting, erosion and weed infestation. For this reason, it is also important to revegetate correctly the first time.

Seeding Rates

Direct seeding rates for individual species and species mixtures should always be derived on a pure live seed (PLS) basis. Pure live seed refers to the portion of a seed lot that is live seed of the desired kind. Seed testing to evaluate purity and germination should have been performed recently to ensure an accurate determination of PLS values.

The suggested mixes should be drill seeded at 15 PLS lbs./acre. The rate for broadcast seeded areas, harsh sites or critical areas should be doubled. This allows greater numbers of seed per unit area to allow for poor seed germination and seedling mortality. The cost of seed is relatively inexpensive compared to many other revegetation procedures and helps to improve the chance of success.

Seed Quality

All seed furnished to the operator should be those specified by the operator and should be measured by PLS weight. All seed should be tested by a certified seed analyst in an accredited seed testing laboratory within 18 months for grass seed, 9 months for forb, shrubs and tree seed, and six months for all seed crossing state lines. Each seed species should be furnished with a tag which clearly lists: (1) botanical name; (2) common name; (3) collection location and elevation; (4) pure seed (%); (5) inert matter (%); (6) other crop seed (%); (7) weed seed (%); (8) noxious weed seed; (9) germination (%); (10) hard seed (%); (11) date tested; (12) lot number; (13) net weight; (14) name of seed testing laboratory (15) name and address of seed company.

All legume seed should be treated with a commercial Rhizobia inoculant at the time of planting in order to enhance the development of nitrogen-fixing root nodules.

Seed should not contain prohibited noxious weed seed as listed by state law. Wet, moldy, or otherwise damaged seed should not be accepted. If a specified seed variety is not available, the contractor consult with the operator prior to any substitutions.

PLANTING

Transplanting live plants or plant parts is an alternative to plant establishment from seed. Because of higher labor and plant material costs associated with transplanting when compared to establishing vegetation from seed, transplanting is usually limited to specific situations. Since transplanting involves plant materials which are more advanced in their development than seed, transplanting allows for more rapid vegetation establishment and more successful establishment in situations where seed germination and seedling establishment are difficult. Therefore, transplanting is most useful in high priority areas where revegetation of critical areas for rapid erosion control may be necessary or where rapid vegetation establishment on highly visible areas may be desired. When revegetating areas of less than 8-9 inches of annual precipitation, precipitation is too low to consistently ensure seed germination and plant establishment from direct seeding, and transplanting is a viable alternative for revegetation. In other harsh sites, where seed germination and seedling establishment is difficult, transplanting is a viable alternative. Establishment from seed is extremely difficult for some shrub and tree species and some form of transplanting may be required to establish these species.

Technique Selection

Transplanting methods can be subdivided into the following categories: bareroot transplants, container-grown transplants, mature plant transplants, sodding and/or sprigging.

Sodding is confined to use with rhizomatous and/or stoloniforous perennial grasses and is not well-suited for perennial grasses of bunchgrass morphology. Since perennial grass establishment can ususally be accomplished effectively via direct seeding, its use will be limited in the Bear River Divide region. Sodding can be an effective technique for rapid stabilization of critical, reconstructed drainages or localized steep slopes. Sodding and sprigging can be used to reestablish grasses which propagate well vegetatively but produce little viable seed. Saltgrass would fall in this category, but because this grass has little applicability in the Bear River Divide region, the use of these techniques for this purpose is limited. For further information on sodding and sprigging see May et al (1971) and Sindelar et al (1973).

Transplanting of mature-sized individuals is generally limited to transplanting nearby native shrubs and trees onto disturbed areas. Since no pruning of the tree or shrub roots has taken place, much of the root is deep and cannot be effectively excavated with the plant. This results commonly in a die-back of the topgrowth and often death of the plant itself.

However, some shrubs and trees, as well as grasses and forbs, can be effectively transplanted within a soil mass and planted into a disturbed area to form "islands" of native seed and root material. These islands would increase the diversity of indigenous species which are impossible to obtain or difficult to establish by seeding and would provide centers for dispersal of these species and the beneficial microorganisms in the soil

mass. The mixed-shrub and aspen vegetation types have the most potential for this technique, since the woody species in these vegetation types are generally more capable of resprouting. The use of these "islands of disemination" is limited to large contiguous areas. Recolonization from adjacent undisturbed areas can be fairly rapid along narrow disturbances for many species.

The main advantage of bareroot plants in comparison with container plants is that bareroot plants are cheaper in purchasing price and because of their lighter weight, are cheaper to ship. Bareroot individuals are harder to plant properly and require greater care in shipping, storage and planting than container plants. Although they can be held in a dormant state in cold storage for short periods of time, there are limits as to when the bareroot stock can be lifted and planted. Advanced planning is necessary to ensure the availability of bareroot material since it usually requires one to two years to produce a bareroot plant. Survival data comparing bareroot and container-grown plants is varied. Bareroot plants are older and have a larger caliper but do not have the advantages of being planted in a growth-medium with a higher water-holding capacity. Van Epps and McKell (1980) indicated that on very harsh sites, success from container plants exceeded bareroot plants.

Although container plants are more expensive, they are more available and permit a greater degree in flexibility than bareroot plants and seem to perform better on extremely harsh sites. If bareroot plants are available for use on the Bear River region, then their use is probably more economical than container plants. However, because of the lack of availability, container-grown plants will probably be the most common form of transplanting.

Planting Techniques

In order to best ensure availability of desired species and proper hardening of plants, plants should be ordered approximately 8 months in advance of planting for tubeling-sized container plants. Larger container sizes are probably not necessary for most reclamation purposes unless more immediate results are desired. On a survival basis, larger container-sized individuals tend to be less cost effective. Advanced ordering of one to two years may be necessary to ensure availabiltiy of bareroot plants.

Plants should be inspected for adequate hardening. Adequate hardening is a necessity for container-grown plants. This requires about two to three months depending upon the season of year. Hardening is the process whereby the plant makes certain physiological and morphological adaptions making the plant better able to withstand adverse conditions. This process is initiated at a nursery by reducing the supply of moisture, altering the nutrient balance, reducing the temperature and increasing the exposure to direct sunlight and ambient conditions that are likely to be experienced at the planting site.

If site conditions are dramatically different from climatic conditions at the nursery it may be advantageous to attempt to site harden the plants for a few weeks or months. However, it should be emphasized that moisture stress that occurs abruptly at the planting site a few days before planting

will do little to harden the plants, since hardening is a developmental process. Therefore, withholding water from containerized stock in an effort to rapidly adapt them to a dry environment just prior to planting may do little more than to unnecessarily stress the plants and weaken them by reducing carbohydrate reserves that are essential for rapid root growth and survival.

Most favorable results from planting generally occur from spring planting. Adequately cold-hardened plants should be planted as soon as access is possible, from mid-April to mid-May, thus taking advantage of soil moisture accumulation during the winter and potential late spring precipitation.

Upon receiving a shipment, plants should be appropriately cared for to maintain them in a healthy and vigorous condition. Personnel should be advised of an incoming shipment and someone should be assigned to care for the plants upon arrival. This is especially important for shipments scheduled to arrive on or near weekends. All shipment boxes should be opened and plants inspected for moisture status. Plants should be watered as soon as possible after they arrive to ensure that each container receives adequate moisture. A garden hose fitted with a soaking spray nozzle works well for this purpose. Plants can generally be left in the shipping container when watered to reduce handling and to avoid mechanical damage.

Appropriate holding facilities should be constructed prior to receiving plants if the plants can not be outplanted within a couple of days. The purpose of using holding facilities are to:

- Avoid or reduce moisture stress.
- Avoid depletion of carbohydrate reserves.
- Avoid excessive heat or cold.
- Protect the plants from mechanical damage due to trampling, wind, mishandling, or animals.
- Provide a convenient staging area for transport to the planting area.

Generally, simple enclosures to discourage animal or human damage along with someone assigned to monitor plant condition is adequate protection for early spring planting, if the plants are adequately cold hardened.

The rooting media should feel moist to the touch. When watered, plants should be given sufficient water to ensure that all of the root column receives moisture, not just the surface layer.

Inadequate light may occur when plants are placed in a dark environment (e.g., left in a closed shipping box or placed in the corner of an office or warehouse.) Frost damage may also occur to hardened plants if plants are warmed up sufficiently (a few days of warm temperatures) to alter the internal cell physiology. When plants having undergone such cell changes are outplanted to freezing temperatures, frost damage or freezing can

result.

Plants should never be covered with plastic or canvas covers without adequate ventilation to allow the dissipation of accumulated heat. Canvas transmits less solar heat than plastic. "Shade cloth" (available from nursery supply houses) that allows different amounts of light to pass through it, or other wind resistant cloth, can be attached to a simple frame to reduce excess heat build-up or to prevent adverse moisture stress. Plants are often severely damaged by excessive exposure to wind. When conditions are hot and dry adequate precautions should be taken to protect container-grown stock. Sideboards or other temporary windbreak materials can be quickly put in place should conditions require. Water stress is generally the most critical factor to monitor during windy periods. Wilted plants will indicate urgent need for moisture.

Bareroot seedlings should be stored at between 34°F and 39°F until outplanted. Field storage for these plants is best with some type of well-insulated storage shed or moist cellar. Storage structures can be cooled by ice or snow. However, solidified carbon dioxide (dry ice) should not be used because it is toxic to seedlings and humans in high concentrations, and its very low temperature, -112°F, could damage seedlings. Seedling storage should be limited to a week or less as storage temperature warms to 39°F. Under ideal storage conditions, some dormant bareroot seedlings can be stored for 90 days or more. However, most native shrubs can not be stored longer than about one week.

Planting should be done by using motor driven augers to excavate planting holes. These motor driven augers are usually of the backpack or hand-held types. In some very rocky or heavy clay soils the use of augers may be difficult. Planting bars, hoedads, picks or planting shovels may be necessary. The hole should be large enough to contain the root or root plug of the plant. Care should be taken that auger operators do not get too far ahead of planters, thus allowing the extracted soil to dry out.

Once the hole is made, a slow release fertilizer tablet such as Agriform (20-10-5) should be placed in the bottom of the hole with a light covering of soil. The plant should then be inserted into the hole. Plants should not be left exposed to dry out. If bareroot stock is used, caution must be excercised during planting to ensure that bending or kinking does not occur. Plants should be positioned as nearly vertical as possible.

Soil is firmed around the plant such that the top of the root plug is 1/2 to 1 inch below the ground surface. This is important to prevent drying of the root plug by water wicking up through the rooting medium to the surface. In rocky soils, care should be taken not to crush the delicate root plug between rocks, thereby stunting the root system and increasing the likelihood of future moisture stress and additional problems with insects and disease.

Planting on steep slopes offers challenges that must be adequately dealt with if plant establishment is to be achieved. Planters should be instructed to begin at the top of the slope and work across and eventually down the slope. There should be no planters working directly below another planter as sloughing from above may bury lower plants and rocks dislodged

may endanger the planter below.

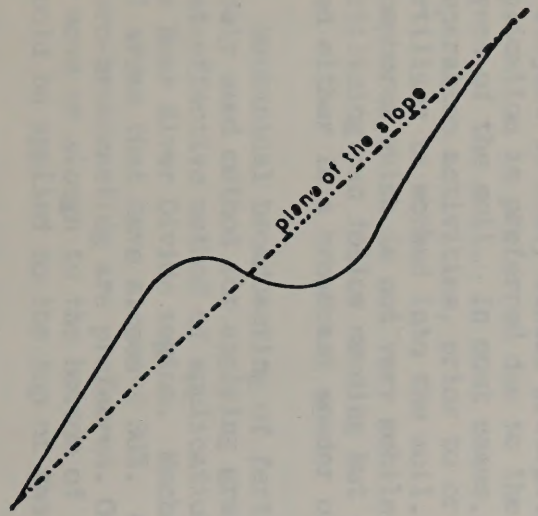
Positioning of the plants on very steep slopes is especially important. Precipitation catchment basins of about one foot in diameter often help to stabilize the slope, increase infiltration, and direct moisture to the plant. Using a hoedad or shovel the above-slope area should be scraped to remove excess soil from above the plant that might otherwise slough off and bury the seedling (Figure 14). Next, a catchment basin is formed and the hole positioned near the outer edge of the lip of the basin (Figure 14). The plant (and in some cases fertilizer tablet) is then inserted and covered.

It is important that the plant be positioned near the outer lip of the catchment basin, to prevent loss due to burial of the plant or exposure of the root system by erosion. The crown of the root plug should be aligned with the plane of the undisturbed slope. In general, soil positioned above the plane of the slope will erode away with time and leave any root plugs in the eroded area exposed. Depressions or basins below the plane of the slope will eventually fill in by sloughing and surface materials washed from upslope, thereby burying any plants positioned in this area. In short, the plane of the slope will tend to reestablish itself with time. This may occur as early as the first event of precipitation or spring snow melt and runoff. It may occur as late as one year later.

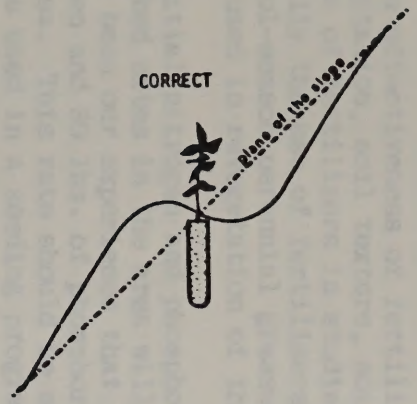
If the soil is not moist at the time of planting, plants should be "watered in" by providing approximately 2 quarts of water per plant.

Animals may be attracted to newly planted or seeded areas due to the lushness and palatability of the vegetation. If animals are attracted in large numbers, serious damage to vegetation may result. Livestock, deer, elk, antelope, rabbits, and rodents are among the animals most likely to create problems. Animal control measures may be necessary.

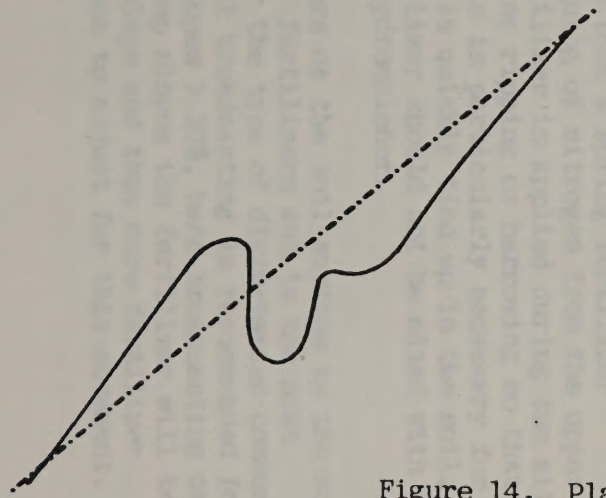
Soil area removed with the first scrape, in preparation for forming the planting basin and hole.



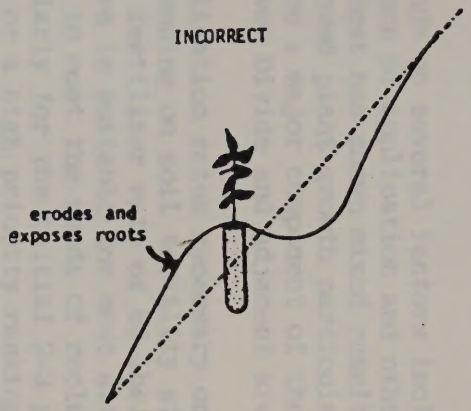
Proper positioning of the plant with respect to the slope and catchment basin.



Precipitation catchment basin and planting hole properly positioned with respect to the slope angle.



Incorrect positioning of the plant with respect to the slope and catchment basins.



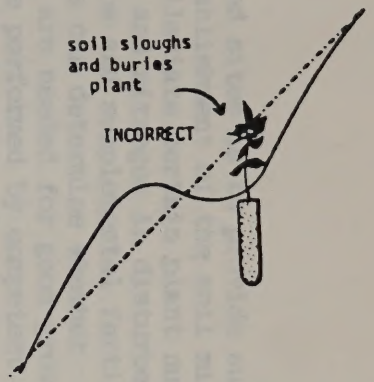
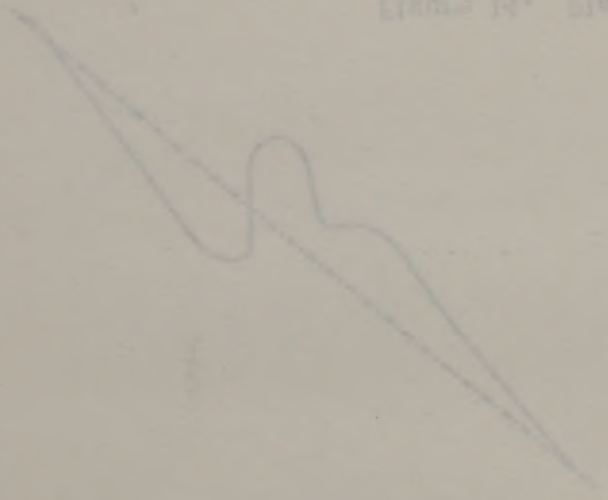


Figure 14. Planting technique for steep slopes.











FERTILIZING

The purpose of fertilizer on disturbed sites is to provide sufficient nutrients for plant growth and the reestablishment of the soil microflora. Although the process of topsoiling can alleviate certain plant nutrient deficiencies, plant available phosphorus and nitrogen in disturbed sites in the Bear River Divide region are often low and supplemental fertilization is required. Site specific soil analysis can determine whether fertilization is required and what rates are needed for good growth of the species planted. Soil analysis should be performed by competent labs that have experience in the Intermountain Area and are familiar with fertilizer rates for reclamation or pasture-type conditions.

The effectiveness of fertilizers depends on several factors including precipitation, soil texture, soil pH, season of application and others. The use of fertilizers in studies in the West has shown mixed results but generally the use of fertilizers has improved plant growth particularly for the cool-season perennial grasses which are a major component of the seed mixes used in revegetation of the Bear River Divide and adjacent areas.

Initial nitrogen and phosphorus fertilization rates necessary on disturbed sites in the area will vary depending on soil fertility status. It has been our experience that a general fertilizer rate of 80 lbs. of nitrogen and 80 lbs. of phosphorus per acre is suitable for most sites in the area. This rate should be sufficient to meet the needs of reclamation species used in a seeding program particularly for the initial 2-3 growing seasons. On areas that have steep slopes or a high priority ranking, a site visit should occur during the third growing season to assess the need for refertilization. The assessment can occur by sampling the soil or by visually assessing the response of the vegetation. Vegetation parameters that show nitrogen deficiencies include slow growth and yellowing or drying of leaves. Phosphorus deficiency symptoms are purplish stem and leaves, slender plants, slow growth and lack of seedheads.

The optimum time of year to apply fertilizer for most areas within the Bear River Divide and adjacent areas is in the fall or spring. If the site is subject to heavy winter precipitation then a spring fertilizer application is preferred due to the leaching of nitrogen from the upper layers of the soil. In most cases, fertilizer is applied during the site preparation activities, prior to or during ripping or harrowing so that the fertilizer is worked into the soil. This is particularly necessary for phosphorus which is not very mobile and is quickly tied up in the soil. Fertilizing can follow seeding but fertilizer should not be mixed with the seed either in a broadcast seeder or a hydromulcher.

Mechanical broadcasting of fertilizers on the soil surface is the most widely used method for applying granular fertilizers and is the most cost-effective method of application for the type of disturbances common in the Bear River Divide region. Mechanical broadcasting is recommended for all areas that have slopes $< 30\%$. On slopes $> 30\%$, hand broadcasting or hydro-broadcasting are preferred. On steep slopes the fertilizer will tend to move or slough to the bottom of the slope and thus more fertilizer should be applied to the top of the slopes to adjust for this movement.

MULCHING

The primary purposes of using mulches on disturbed sites in the Bear River Divide region are two fold: control of erosion and moisture conservation. On steep slopes the mulch acts as a protection of the soil against rainfall and overland flow of water which reduces erosion. On the drier sites the mulch acts to conserve moisture conservation and reduces evaporation. Analyses of the effectiveness of mulch in southwestern Wyoming show that mulch is useful in benefitting revegetation by retarding evaporation, increasing infiltration of rainwater, protecting the soil and seed against impact of raindrops, intercepting surface runoff, reducing soil temperature ranges and generally increasing seedling establishment (Smith 1981). Where annual precipitation is between 10 and 18 inches, mulches are highly conducive to seedling establishment. This is particularly true of south and west facing slopes. In areas where the annual precipitation is between 18 and 25 inches, mulches are generally not needed except as a protection against soil erosion.

Criteria for Selection

Field analysis of the disturbed sites in the Bear River Divide region showed that the use of a mulch should be required on all slopes > 3:1 to reduce erosion (OIA 1985). On these sites the use of netting or tacking is nearly always required to hold the mulch. On high priority areas, an excelsior (wood fiber mulch with plastic netting) blanket or straw with a plastic netting appears to be the most cost-effective techniques for reducing erosion while allowing for a stable vegetative cover to develop. On low priority sites straw held with a tackifier is recommended. The tackifier is less expensive than netting but is not as effective under very windy conditions which are common in the Bear River Divide region.

On slopes that are more gentle, < 3:1, the recommended practice is to crimp the mulch. Crimping anchors the mulch by partially incorporating it into the soil. Some of the mulch fibers stand on end so that they project above the soil surface, creating ideal conditions for trapping snowfall and increasing the precipitation on the site. For the dry and intermediate moisture sites, this would be the primary purpose of the mulch. On the moist sites the main purpose of the mulch is soil protection and hence mulch is recommended only on the 3:1-5:1 slopes and on the high priority sites of 5:1-7:1 slopes.

Cost effective analysis of mulches in the study area showed that on steep slopes, mulch was beneficial for increasing seedling density and cover and for decreasing erosion. On less steep slopes, mulch did not have a significant effect on the vegetation but still was effective at reducing erosion. On steep slopes the use of a tackifier was also beneficial over mulch with no tackifier for increasing seedling density and cover and for reducing erosion (OIA 1985).

General specifications

Mulch should be a clean native grass hay or cereal straw. Since hay or straw mulch is a common source of weed seed in reclamation planting, it should be inspected and certified by the state agricultural inspector to be

free of weeds, particularly noxious weeds before delivery is accepted. Straw or hay mulch should have a minimum fiber length of eight inches. The fiber length is necessary to ensure proper anchoring, when the mulch is crimped, netted or tacked. Mulch should be applied at a rate of 3,000 lbs. per acre. The mulch should also have a moisture content of no more than 20 percent. Mulch with a high moisture content is difficult to apply uniformly and the specified application rate is not provided due to the higher water weight. Straw or hay mulch should be free of mold or other unspecified material. Broken bales should be rejected because of their difficulty in handling.

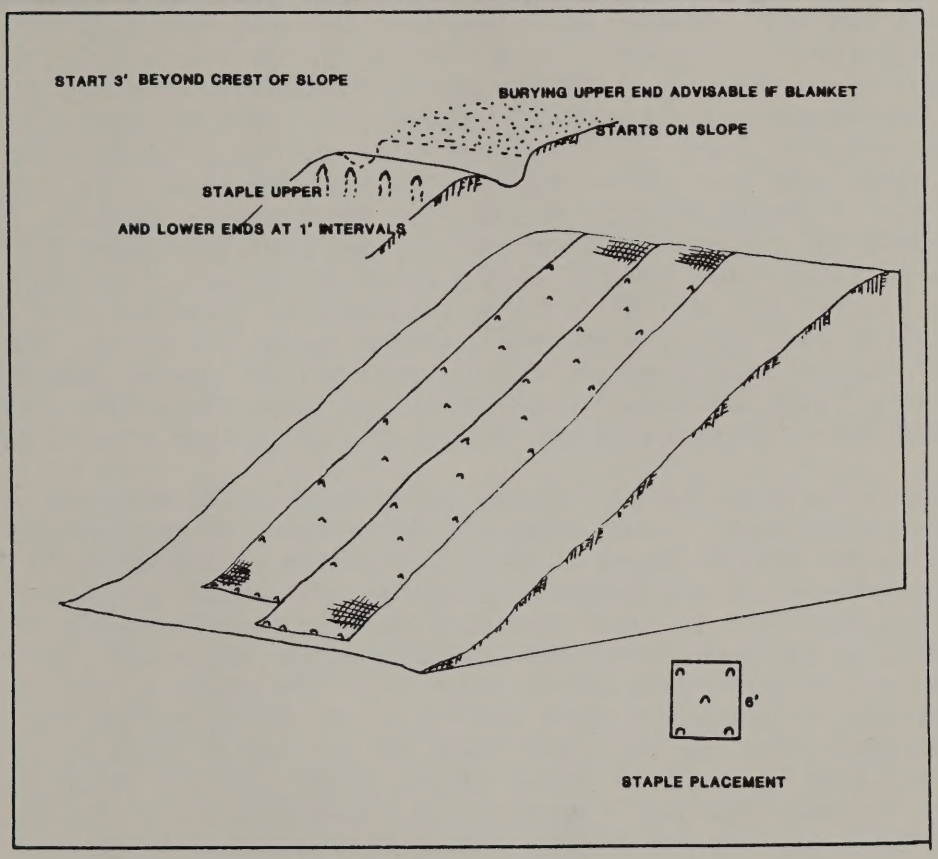
Straw and hay mulches are generally applied with a power blower. The blower breaks apart the straw or hay bale without shattering the fiber and blows the fibers out over the seed bed. The blower can spread mulch approximately 50 feet or more depending on wind speed and direction. Straw and hay are also spread by hand particularly on inaccessable areas and steep slopes. Hand spreading generally requires more hay or straw (approximately 3,500 - 4,000 lbs. per acre) because the bale is not broken apart as easily and tends to clump.

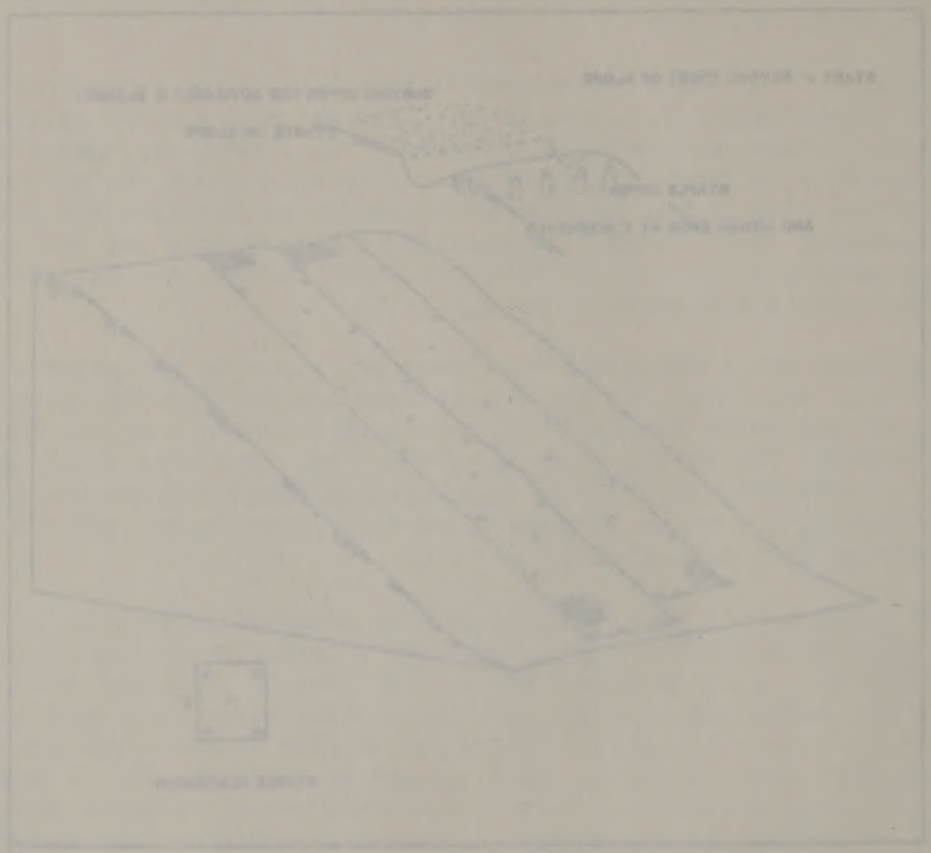
On areas where equipment can traverse, straw or hay mulch is best anchored by crimping. To get the maximum benefit from crimping, the fiber length of the mulch should be at least eight inches long and the soil uncompacted. The mulch should be crimped into the soil about two inches in depth. Blunt-notched disks or specially designed rollers should be used for anchoring the mulch because round disks tend to cut the fibers instead of crimping them into the soil.

On steep slopes mulch is anchored by chemical tackifiers or photodegradable plastic mesh. Chemical tackifiers are best applied with a hydromulcher. A recommended rate of 120 lbs. of tackifier with 300 lbs. of wood fiber mulch per acre is mixed in a water slurry and applied evenly over the straw or hay mulch. Rates may differ with various products and the manufacturers suggested rates should be applied. On critical sites that are steep and subject to erosion, mulch with a plastic netting or an excelsior blanket is recommended. The excelsior is rolled out over the seedbed and stapled at regular intervals in order to anchor the mat in place (Figure 15). When applying netting a trench is made at the top of the slope and the ends buried to prevent water from running underneath the netting. The netting is stapled at three foot intervals and one and a half foot intervals along the sides and bottom. A U-shaped staple is generally used ranging from 6 to 12 inches in length. Shorter staples are used on rocky or non-topsoiled slopes. On extremely rocky or compacted soil surfaces, rocks or other objects may need to be placed on top of the netting to hold it in place. Manufactures specifications should be used in most cases as to the application of excelsior blankets and stapling requirements.

Nurse (companion) crops are fast growing annuals (barley, wheat, etc.) which are seeded along with the revegetation mix and which provide live mulch benefits to the slower growing (perennial) species. Because the nurse crop germinates and establishes at the same time as the perennial crop, competition for moisture will occur in dryer areas. Therefore, nurse crops are not recommended for use in the dry or intermediate

Figure 15. Schematic showing proper installation of excelsior mat.





moisture regime.

Stubble mulches are similar to nurse crops except that they are seeded separately and sufficently prior to the perennial mix to allow the annual crop to mature and die. The perennial mix must be drill seeded into the stubble mulch in order to provide seed contact with mineral soil. The disadvantage of stubble mulches is that under drought or other harsh conditions, the annual crop may fail, in which case a contingency plan must be implemented in order to provide adequate mulching protection.

MONITORING AND MAINTENANCE

The purpose behind a monitoring and maintenance program is to locate, identify and solve problems before they escalate and become more serious and expensive to correct. Monitoring and corrective maintenance is perhaps the most overlooked part of a reclamation program. Yet it is an area that has potential for considerable cost savings for a company. For example, if one is using terraces to control water on a fairly steep slope then it is important to ensure that the terraces drain properly, not too steeply to cause erosion or not so gently that water collects. It is difficult to evaluate the effectiveness of terraces until a rainfall event has occurred. If the terraces do not drain correctly then water can accumulate. This water will either percolate into the soil or if there is sufficient rain the water will spill over the edge of the terrace and will cause very serious erosion. The erosion will not be confined simply to the slope just below the improperly constructed terrace but very often the force of the water from the break in the terrace will cause a chain reaction of breaks in the terraces below causing gullies of up to six feet deep. In this case, instead of fixing one terrace, the operator may have to fix five to ten terraces as well as the deep gullies on the slopes between the terraces. The costs would be considerably larger and could have been avoided by site monitoring and appropriate maintenance activities.

The schedule of the monitoring and maintenance activities are dependent upon the reclamation program that is implemented. Monitoring should occur during construction to ensure that work is being carried out according to specifications. Correction of improper techniques or miscommunications are far more effective and far less expensive early in the construction activites. The major emphasis of the monitoring programs is after construction is completed. A minimum of two monitoring visits per year should be considered for the first two years following the reclamation for the high priority sites, and at least one visit per year should be made for the low priority sites. These visits should be timed so that the maximum benefits can be obtained such as following a rainfall event to evaluate water management techniques or at the peak of the growing season to assess the success of the reseeding.

The monitoring visit need not involve extensive data gathering on species density or production. An alternative approach of a rapid qualitative assessment of species establishment and growth and identification of problem areas could provide much more information with considerably less cost. The value of such a monitoring program is very real and does provide valuable information for not only improving future reclamation by selecting those techniques or species that performed the best but can provide cost savings by eliminating those aspects of the reclamation plan that were not effective.

A monitoring program would be useless unless a maintenance program is part of the reclamation plan. Identifying problem areas is only the first step, the real benefit to the operator is in the correction of those problems in a timely manner, resulting in real cost savings.

SPECIAL PROBLEMS AND CONSIDERATIONS

The reclamation techniques described above should address most of the problems that would normally be encountered in site reclamation in the Bear River Divide region. However, some areas may have special problems or may require special consideration for successful clamation. These areas were identified in the Appendix I and II (OIA 1985) reports. Techniques for addressing these problem areas are introduced in the following sections and should provide the user with a general knowledge. References are given to appropriate resources if further information is needed.

GRAZING

As noted in Appendix II (OIA 1985), grazing on newly reclaimed areas can be a significant problem. New, establishing plants do not have the carbohydrate reserves to sustain continued defoliation. They are susceptible to being easily uprooted when grazed or when trampled. These new plants are often more succulent and tender than those in adjacent, undisturbed vegetation, attracting grazing animals and compounding the problem of revegetating areas that are simultaneously being grazed.

Ideally, newly revegetated areas should be deferred from grazing for two growing seasons. Those receiving higher precipitation can be grazed lightly at the end of the second growing season. This includes the mixed-shrub, aspen and conifer zones. Often, however, the oil and gas operator does not have direct control over the grazing operation and it is difficult to control stocking rates and duration of grazing.

The most effective way to control grazing is to fence revegetated areas. This is possible on drill sites and large contiguous disturbances but is impractical on pipelines, roads, and other long, narrow disturbances. Fencing, although expensive, is recommended for drill sites. This protects the oil and gas operator by allowing sufficient time for vegetation establishment so that goals established by the land owner or manager can be reached. Fencing usually is implemented on operating well sites in order to protect equipment and livestock.

Standard three or four-strand barbed wire fences can be used successfully to control grazing. The recommended heights for four-strand cattle fences are 16-22-28-40 inches (U.S.D.A. Bureau of Land Management 1981) or 15-23-31-42 (Wyoming Department Environmental Quality 1984). The BLM recommends that a three strand fence have heights of 16-26-38 inches. In addition, the BLM fencing standards specify that both four- and three-strand cattle fences have a barbless top strand, all other strands should be barbed. Four-strand fences should be used as perimeter fences or when cattle concentrations are high. On relatively even terrain, suspension fences are recommended. These fences are similar to conventional four-strand fences except that spacings are 80 to 120 feet between line posts. Twisted wire stays are placed every 15 feet between line posts to prevent cattle from forcing the wires apart (Vallentine 1980). The quality and setting of corner and brace posts are particularly important in suspension fences. Suspension fences require fewer line

posts, the cost of materials is reduced from one-half to two-thirds the cost of standard fence and maintenance costs are also usually lower.

Many disturbances may occur in areas that are less affected by grazing animals. Areas of steep terrain or that are removed from water sources may receive only light grazing and therefore may not need any specific grazing control. The lack of signs of cattle use can be used to identify these areas or the livestock manager may be aware of them.

Agreements can be made with the livestock manager to defer grazing from unfenced areas. This may require monetary compensation but may be cheaper than fencing. Assistance can be given to the livestock manager to develop a supplemental feeding program to keep livestock off from revegetated areas. The revegetation specialist should coordinate revegetation activities closely with the livestock manager. Salt and supplemental feeders should not be placed near revegetated areas. Grazing while plants are dormant is usually the time when defoliation is least damaging. Deferment until late fall will cause the least damage to revegetated areas.

It is difficult to control livestock use of long narrow reclaimed corridors. Not only do these areas provide a succulent alternative to the adjacent rangeland, but they provide a nice straight walkway free from brush and other obstacles. It is important to encourage rapid revegetation of these areas so that they can recover quickly. Minimal disturbance of the topsoil will encourage rapid reinvasion and establishment of native and other desired species. Replacing cleared brush back onto these corridors will help discourage livestock travel.

WEED CONTROL

As also noted in the Appendix II report (OIA 1985), weeds present localized problems on disturbed sites in the Bear River Divide region. The largest problem comes from Canadian thistle and musk thistle. These perennial thistles are aggressive and can invade reclaimed areas, particulary if overgrazed, as well as becoming established from seed during the initial disturbance.

Other weed problems result primarily from the initial disturbance and include cheatgrass, pigweed, henbane, Russian thistle, knotweed, and pennycress. Henbane, an annual or biennial, has localized heavy occurrences, primarily in Rich County. It appears to be confined to disturbed areas and does not encroach upon native rangelands. This implies that it would not be a problem on established reclamation sites. Although henbane is poisonous, it is unpalatable and not widely utilized by livestock. Knotweed, although a perennial, is short in stature, will probably not significantly affect the establishment of more desirable species, and will eventually be out-competed by other perennial species. Heavy stands of cheatgrass will usually not develop unless it was a dominant plant prior to disturbance. If cheatgrass was a dominant plant prior to disturbance, control of this species may be necessary. The other annual weeds; pigweed, halogeton, Russian thistle, and pennycress may be common the first one-two years following revegetation, but in most sites begin to be crowded out by the perennial vegetation the third year

following reclamation. This is particularly true in those areas receiving over 11 inches of annual precipitation. Although dyer's woad was not a major problem along the Bear River Divide and adjacent areas, a careful watch for this species be maintained. This noxious weed has infested several adjacent counties.

An important step in minimizing weed problems is to survey the topsoil that is to be stockpiled for weed infestations and to survey surrounding areas, particularly upwind, for potential sources of weed seed. If heavy infestation already exist, weed control should be initiated. If perennial thistles already exist in the topsoil, these should be spot treated. The rhizomes from Canadian thistle can develop into a large problem if not controlled. If the potential for infestation from adjacent areas is high, close monitoring of weed establishment on revegetated areas should be initiated. Replaced topsoil should be seeded as soon as possible in the nearest seeding window to minimize an accumulation of weed seed or weed establishment prior to seeding. Mulch, a common carrier of weed seed, should be certified weed-free.

Additional weed control may become necessary if weeds become established. In most cases, annuals will be outcompeted in about three years and no additonal treatment is needed. Additional disturbances should be avoided since they will prolong the presence of weedy species.

Preemergent herbicides are used to control the germination of weed seed. These herbicides are usually not selective and will kill all new seedlings, including desirable species but will not affect established plants. They have the greatest potential in controlling annuals. Since a large portion of the seed from annual species germinate the year following their development, one herbicide application can severely reduce the population of annual species. Since perennial plants live longer than one year, they will continue to produce seed and the year following the herbicide application, seedlings will begin to establish. These herbicides could be used in controlling cheatgrass and henbane. Since henbane is a biennial, two applications (one year apart) should severely reduce these populations allowing the perennial species to become better established. Preemergent herbicides should be applied shortly before anticipated germination and require precipitation or wetting to become effective. Some preemergent herbicides require incorporation into the soil. Simazine is a preemergent herbicide that does not require incorporation into the soil and costs around $8-16/acre.

Mowing, prior to seed production, can also be effective in eliminating seed production and thus reducing the restablishment of annual species. This technique is limited to slopes that are accessible to equipment (<3:1) and is commonly used in controlling weeds on large coal mines.

The application of 2,4-DB can be used to control nonleguminous, broadleaf weeds. It is most effective when plants are young, less than three inches tall or prior to early bloom, but are actively growing. This herbicide will not affect grasses, legumes (except sweetclover) and shrubs. It can be used to severely knock back perennial thistles and costs approximately $3-6/acre. It is also effective in controlling jimson weed, a close relative to henbane, and therefore may be successful in controlling

henbane as well.

Glyphosate ('Roundup') can be spot-applied to infestations of perennial thistles and these areas can be reseeded in seven days. Glyphosate is nonselective and will kill all vegetation it comes in contact with and therefore should be spot-applied. It has no residual affect on the soil and costs approximately $40-60/acre.

When applying herbicides, care must be taken to ensure environmental and human safety. Contractors must be licensed. Labels should be followed and all cautions and warnings should be heeded. Apply only as directed. Avoid contamination of water bodies and do not spray on windy days to avoid excessive drift onto adjacent areas. Check with the landowner prior to applying the herbicide.

Insect control of seed production in musk thistle is currently being tried. Although the long-term effect of this approach is unknown, continued efforts along this line are encouraged since it could prove to be a long-term, regional-wide control.

SOIL AMENDMENTS

Soil amendments are additive chemical treatments which ameliorate soil conditions unfavorable to plant growth such as high acidity, salinity or alkalinity. The field survey of reclamation practices in the Bear River Divide region (Appendix II, OIA 1984) shows that soil amendments are generally not necessary for successful reclamation. The only areas that might be problematic would be lowland soils or playas where salts may tend to accumulate or on soils derived from specific geologic strata that have high salt contents or other unusual properties.

The principle amendments needed in these conditions are those that reduce the salts and pH of a site. The salt that is most problematic is generally sodium and sodium affected (alkaline) soils are also the most difficult to correct. Two techniques are often used to correct alkaline soils: application of gypsum or sulfur and leaching. The rate of application of these compounds is dependent on the concentration of sodium in the soil, soil textures, permeability, soil moisture and other factors. For recommendations on application rates the U.S.D.A.'s Diagnosis and Improvement of Saline and Alkaline Soils should be consulted (U.S.D.A. 1969). These chemical additives are usually applied by broadcasting and are then incorporated into the soil by disking or plowing. Thorough incorporation is important when using sulfur to ensure rapid oxidation to the sulfate form. If water is available, leaching may be used to improve sodium affected soils. Leaching is the application of water in a downward flow through the soil to dissolve sodium ions and transport them below the root zone. It's success depends on: satisfactory water quality and sufficient drainage to ensure a <u>downward</u> flow (evaporation can create a significate upward flow). Because sodium affected soils are often low in permeability, the application of lime or sulfur may be a prerequisite to successful leaching.

SPILLS AND RESERVE PIT REHABILITATION

The development of oil and gas reserves requires the use of specially formulated muds to aid in the drilling process. These muds are used to lubricate and cool the drill bits, prevent corrosion of metal parts, maintain pressure, keep additives suspended, facilitate the removal of cuttings produced during the drilling operations, and restrict the growth of bacteria and fungi that may adversely affect the drilling process. There are literally hundreds of mud system products on the market today. They include such things as clays, vegetable gums, organic fibers, salts, hydrocarbons, and chemical additives. A few of these additives are potentially toxic to living organisms. They include such things as bactericides, chrome/ferrochrome lignosulfonnates, polysaccharides, zinc chromate, aldehydes, phenols, salts, and aromatic and aliphatic hydrocarbons. Increasing toxicity of drilling muds is usually positively correlated with greater hole depth, penetration of saline shales, and procedures used by certain companies.

Exploration mud usually includes the less toxic mud system components and the disposal volumes generally do not pose major problems; however, the disposal magnitude and toxicity can increase once a field enters the development stage. Workover rigs also produce highly saline and/or toxic muds. During drilling, the mud is pumped into a reserve pit. Several options for reserve pit reclamation are available to the industry. These include evaporation, land application, obtaining an NPDES discharge permit, if the effluent quality criteria can be met by in-pit treatment, or by underground injection into an approved well site. Sludge pits may be backfilled after drying if hydrologic isolation can be demonstrated. Sludges may be land applied depending on sludge quality and site characteristics, or they may be hauled to a state-approved disposal site. A common practice in the Bear River Divide area is that at the conclusion of the drilling program, the pits are allowed to evaporate, the supernatent is pumped out with the used mud system and wastes are covered over with the berm material.

In actual field conditions, the pits are usually left open for extended periods of time, collecting both rain and snowmelt, which may generate a much larger contaminated fluids problems. Occasionally, fluids may build to the point that a breach in the reserve pit berm results in spilling the drilling fluids onto adjacent land and streams. These highly saline, and often toxic muds require immediate attention to minimize any adverse impacts to the surface and ground water quality and vegetation/wildlife of the area.

Clean-up procedures involve the immediate construction of emergency siphon dams, check dams, and settling ponds to retain the fluids and any residual oil until final cleanup activities can be initiated. Surface deposits of the drilling fluids are usually collected and deposited at state approved depositories or in the repaired reserve pit. Disturbed areas are then treated with conventional reclamation practices to control erosion and reestablish vegetation. In the event that it is impossible to collect or transport all of the contaminated materials to an acceptable disposal site, then treatments may be considered with the approval of the state agency (e.g., the Wyoming DEQ, Water Quality Division) to reduce any

toxic substances to "acceptable" levels, levels usually defined by law.

Biological degradation of oil and grease fractions, as well as several organic compounds can be encouraged by ensuring that the contaminated soils are well mixed to more evenly distribute the organic compounds or commercial dispersants may be utilized with the approval of the state agency. Oil and grease fractions above 4% are usually considered toxic to plant growth and require periodic (e.g., every three to four months) aeration of the soil before attempts are made to revegetate the surface. This process may require from 1 to 2 years to reduce 90 to 95% of the oil and grease fraction. Proper soil aeration through conventional tillage practices encourages biodegradation as do soil moisture levels that approach 70% of field moisture capacity. Colder soil temperatures (lower than 50^{o}F) and dryer soil conditions may require even more time for biodegradation.

Because of the potential for such contaminated soils to crust over and dry out due to the bentonite clays in the drilling fluids, it is usually adviseable to cover the contaminated soils with a layer of topsoil if available. If the contaminated soils have high salinity levels (e.g., electrical conductivity values above 8 mmhos/cm at 25^{o}C) then a capillary barrier may be required to discourage movement of the salts to the soil surface. Mulches can also be used to reduce the movement of soluble salts to the surface through reduced evaporation and help create a more favorable medium for plant establishment. Selection of species may require the use of salt- and drought-tolerant species.

It is a general practice among most drilling companies to utilize large quantities of water in the drilling process, thereby requiring large reserve pits. These pits present a threat of failure (breaching) in hilly or mountanous terrain, and increase the cost of site reclamation. In high priority areas where the risk of such failure is unacceptable, as may occur in areas of extreme environmental concern, it is advisable to attempt to reduce the size of the reserve pit by developing closed mud systems, by which on-rig equipment settles out the mud, rock and metal fragments and recycles a smaller volume of water. Often such procedures may be more economical than hauling water and delays in reclamation due to the need to evaporate the larger pits. It is also desirable in steep terrain to construct earthen pits by hillside cuts, rather than from fill material. Pits should be fenced.

Because each of the three states have slightly different, and often changing regulations governing the disposal of drilling fluids and the subsequent clean-up of any spilled fluids, it is advisable to check with the appropriate state offices to determine which remedial practices are acceptable before commencing drilling operations in an area. In many instances a lack of understanding of proper and acceptable procedures at the time of a spill has resulted in costly repercussions that might have been avoided had the person responsible for clean-up and reclamation been acquainted with legal operating procedures and had an acceptable clean-up plan.

ANIMAL DAMAGE

The primary goal of the revegetation manual is to provide techniques for the reestablishment of wildlife habitat. It therefore seems a paradox that the animal usage we are trying to reestablish can also be a concern. Young, establishing plants do not have the carbohydrate reserves to withstand prolonged defoliation whether this damage is from livestock or wildlife. Rodents or birds can remove seeds before they can germinate and larger mammals can damage newly establishing plants. In general, wildlife damage on grass seedings in the Bear River region should be minimal since seed of this life form is plentiful, germinates readily, establishes quickly, and usually does not form a large portion of the diet. Wildlife damage on establishing shrubs, however, can be a problem. These shrubs are smaller in stature and are generally more succulent than those in the adjacent rangeland. Many shrubs and trees are incapable of resprouting if grazed too close to the ground.

Protection from wildlife damage is much more difficult to provide than protection from livestock damage. Standard livestock fences will not control wildlife and wildlife fences are expensive to establish on reclaimed areas. Protection of shrub establishment from seed is impractical for the most part, although several techniques for the protection of seed from rodents and birds have been tried. Endrin is one of the few chlorinated hydrocarbon insecticides still available for limited use in protection of conifer seeds. Endrin is mainly used for protection from deer mice. The formulation is lethal to some small mammals and birds and is not recommend for use. Other repellents for birds have not been thoroughly tested. Other toxicants are available for rodents and rabbits but are not recommended for use. To protect seedings, the area would have to be excluded from wildlife. Using unpalatable species defeats the objective of wildlife establishment and therefore is constrained to use in areas where the purpose of establishing shrubs and trees is not for wildlife forage.

Protection of transplanted shrubs and trees from wildlife damage is possible. Because of the expense to establish shrubs and trees from transplants, protection from wildlife damage is recommended in areas of heavy rabbit or deer populations. Rabbit populations can quickly destroy complete plantings. Plastic mesh tubing material such as Vexar, can be used effectively to protect young seedlings. These materials usually prove cost-effective, particularly in areas of heavy rabbit concentrations. Since snow accumulations can knock over tubing material, a small support rod (a bamboo stake is effective and inexpensive) should be used. The tubing should be anchored to the ground with staples. In some comparisons between the use of Vexar and no browsing control in the Uintah Basin, plants without protection were grazed completely to the ground in less than two weeks while the protected plants were left untouched (NPI 1983).

Foliar repellents are available but must be applied periodically during the growing season and success has been varied. These applications are generally not cost-effective in reclamation situations.

MANAGEMENT OF BLOWING SNOW

Accumulations of blowing snow in the Bear River Divide and adjacent areas often create numerous problems along roads, drill sites, and other facilities. Snow drifts may block access to drill sites and other facilities, thereby disrupting equipment maintenance and other operations. Snow drifts and blowing snow may increase the risk of traffic accidents and encourage severe erosion when the snow melts in the spring. Spring runoff from snowdrifts in some areas has been observed to remove newly-established revegetation efforts and even destroy well-established stands of natural vegetation. These problems require considerable effort to rectify and contribute significantly to maintenance and snow removal costs.

Snow removal efforts can be substantial at some sites due to topographic and vegetation conditions prevalent at the site. Improper snow removal efforts may create further problems by relocating snow to critical areas that are susceptible to erosion. Understanding how and why snow accumulates can help to avoid many of these problems and reduce costs of maintenance and snow removal. Additionally, an understanding of blowing snow mechanics can assist the revegetation scientist to enhance wildlife habitat by redirecting such moisture to needed areas for wildlife use and to supply moisture for establishing species of plants that help create wildlife habitat.

In many areas of the Bear River Divide region, snow movement in the winter is a common phenomenon. Often the effects of such movement is not obvious or apparent to the untrained observer until blowing snow particles begin to accumulate behind vertical projections, such as ridges, hills, berms, or other topographic features that rise above the horizontal ground surface. Maximum snow accumulations are controlled by the height, density (referred to as porosity), and other characteristics of these vertical projections. As snow particles are moved by wind they normally tend to fill in, mostly behind, but to a lesser degree in front of, rocks, mounds of earth, stems of trees, shrubs, and even shorter grasses and forbs until a relatively predictable amount of snow has accumulated. Snow does not accumulate beyond this amount and any additional snow particles reaching the area are moved on to other vertical projections or obstacles that trap these particles until the maximum accumulation has been reached.

Snow movement is usually greatest, and with the least amount of snow accumulation, in areas that are relatively level and where there are few vertical projections above the horizontal ground surface (i.e., a relatively smooth, flat surface). Large open areas such as fields, meadows, cleared rights-of-way, and drill pads serve as sources of snow that can be moved readily by the wind into adjacent areas where snow accumulates around vertical projections or at the crest of hills or the edge of escarpments. These source areas are often referred to as "fetch" areas.

The volume of snow available from these fetch areas for redistribution is determined by several factors including the amount of snow above the vertical projections at the ground surface. The longer the area along the axis of the prevailing wind, the greater the snow depth above the surface projections, and the smoother the vertical surface distortions, the greater

the amount of snow available for redistribution. The removal of higher forms of vegetation such as trees and shrubs from large areas often releases snow in these areas and makes it available for redistribution. For this reason, it is not uncommon to encounter snow accumulation problems after clearing taller woody vegetation from an area where previously no snow accumulation problems exisited. It is therefore wise to avoid any unnecessary clearing of the vegetation or smoothing of the land adjacent to areas where snow accumulation may become problematic. This may be especially critical for areas adjacent to pipeline rights-of-way that cross wind swept ridge tops. Snow often accumulates at the crests of such ridges several meters deep. Upon melting it creates substantial amounts of water that scour down the pipeline corridor causing severe erosion and possible damage to the pipeline's integrity.

The construction of snow fences in areas prone to heavy accumulations of snow can help to to alleviate many of the aforementioned problems and reduce snow-removal costs. If snow fences are to be successful, they must be designed with sufficient capacity to store the volume of snow transported over the course of a season. If the storage capacity of the fence is exceeded then the snow continues to drift into adjacent areas. It may be necessary, in some areas, to construct multiple rows of fences to store all of the seasonal snow. It is estimated that snow-removal costs along highways can be reduced by more than one-third as a result of the effective elimination of snowdrifts. Effectiveness of the snow fences is attributed primarily to adequate snow-storage capacity and the use of tall (about 12 1/2 feet) fences.

Two types of snow fences are most commonly used in Wyoming: the horizontal-slat fences and the vertical-slat fences. The horizontal-slat "Wyoming" fences are of the standard design used since 1971 by the Wyoming State Highway Department. These structures consist of horizontal boards about 6 inches wide separated by 6 inch spaces, a bottom gap of approximately 0.1 times the fence height (H), and a 15 degree inclination down-wind. Net porosity (open area) of the structure, excluding the bottom gap, is 48%, but averages about 50% over the total height. A bottom gap is necessary to remove snow immediately adjacent to the fence bottom thereby preventing snow accumulation that frequently damages the fence.

The vertical-slat fences are of the typical wood lath and twisted wire construction, often referred to as "Canadian" fencing. Typical dimensions include slats 1 1/2 inches wide, spaced at 2 1/6 inches, resulting in a porosity of about 59%. These fences are usually installed vertically, with a 6 inch bottom gap. Fences installed without a bottom gap are often damaged by accumulating snow and are relatively short-lived. The vertical-slat woven wire fence is reported to be only about 78% as effective as the Wyoming Highway Department standard-plan fence (based on capacity). They are however, less expensive to construct, and more suited for temporary needs.

Geometry of the snow drifts behind the fences is quite predictable based on carefully established models by research hydrologists at the Rocky Mountain Forest and Range Experiment Station in Laramie, Wyoming (Forest Service, USDA). Maximum length of snow accumulation on the leeward side of the horizontal-slat fence is approximately 30 times the height of the fence

(H). The maximum depth is 1.2 H and the location of the maximum depth is 6.7 H. For a vertical-slat fence the maximum length of snow accumulation on the leeward side of the fence is 26.5 times the height of the fence (H). The maximum depth is 1.06 H. The location of the maximum depth is 5.7 H.

Use of such geometric data is useful in determining the minimum distance a fence should be placed up-wind of the protected areas (for example a road or newly revegetated slope), as well as proper spacing between multiple rows of fencing. For example, it would not be cost-effective to place any snow fences closer than 30 times the height of the fence to a protected area or another fence.

There are a variety of factors that should be taken into consideration before attempting to design a snowfence system. The reader is encouraged to contact knowledgeable individuals that can assist them in determining the cost-effectiveness of constructing various snow fence designs. Construction specifications and line drawings are available from the Wyoming State Highway Department in Cheyenne, Wyoming to assist engineers with construction and suggestions for specifications to help in designing and building the more permanent Wyoming Highway Department Wood or Metal Snow Fences. Hydrologists at the USDA Forest Service, Rocky Mountain Forest and Range Experiment Station in Laramie, Wyoming are also excellent sources of information and can assist with suggestions for temporary snow fencing or fencing requiring special design. We have included a brief outline in Appendix B, describing "Snow Control with Road Design and Snow Fences," as provided by Dr. Ronald D. Tabler of the Rocky Mountain Forest and Range Experiment Station in Laramie, Wyoming.

The principles of snow management are also useful in manipulating transported snow into target areas where melting snow will help contribute moisture to vegetation or to ponds to provide additional water to livestock and wildlife. Surface manipulations by contour furrowing, pitting, and planting taller grasses (e.g., Russian wildrye, Altai wildrye, and green needle grass) in narrow strips with unseeded smooth areas in between the strips (or alternatively seeded with shrubs and forbs), may provide additional moisture for plant establishment of both grasses and shrubs. It has been reported that such snowcatching arrangements may increase seasonal moisture for the site of from 4 to 10 inches of water. It should be pointed out that not all species of plants respond equally to additional quantities of moisture. Some grasses (e.g., crested wheatgrass) apparently do not take advantage of the additional soil moisture while other grasses do (e.g., thickspike and western wheatgrass). Several species of shrubs are reported to be adversely affected by heavy snow accumulations behind snow fences, which tended to mechanically damage brittle stems and branches. Russian olive, Siberian peashrub, and white rabbitbrush were reported to be among the most tolerant to snow accumulations, although response of other shrubs should probably be verified through site specific field trials before any significant acreages are planted for the purposes of providing shelterbelts with snowcatching qualities.

The use of snowfences to catch snow that is subsequently directed to stock ponds has also been used successfully in some areas, although certain site conditions such as highly permeable soils between the snowdrift and the stock pond, may make such a usage unfeasible. It is suggested that

those interested in the use of snow fences to augment local water supplies for wildlife or livestock use should contact knowledgeable individuals before attempting such a project.

In summary, the use of snow fencing can provide a very reasonable alternative to other more expensive snow removal and handling techniques for areas experiencing ongoing problems of snow accumulation. More importantly, an understanding of these principles can help to avoid or minimize future problems by helping to properly located roads and facilities, design drift free roads and right-of-way, and to anticipate future problems so that proper site drainage and erosion control techniques can be designed to mitigate the adverse effects of spring runoff from these snow drifts. An understanding of these principles will also help in designing revegetation plans that take advantage of natural ways of accumulating and utilizing melt waters for the establishment of wildlife habitat and sources of water for wildlife.

For more information, the reader is referred to the Appendix I report (OIA 1985) which provides a bibliography of literature dealing with the management of blowing snow.

RIPARIAN ZONES AND WETLANDS

Riparian zones and wetlands play a very significant role in wildlife survival, flood control and water quality particularly in the semi-arid regions of the West. This important role has led to numerous regulations dealing with degradation, pollution or disturbances. All operations should be conducted so as not to cause pollution or change the character of streams, lakes, ponds, waterholes, seeps or marshes. This relates directly to damages caused to fish and wildlife resources. The banks along streams, lakes, ponds and waterholes are considered riparian zones, while seeps and marshes along with wet meadows, shrub and wooded swamps, bogs, salt flats and some playas can all be lumped under the classification know as wetlands.

There are several laws governing the use of wetlands and riparian zones. One of the most comprehensive is section 404 of the Federal Clean Water Act of 1977. The purpose of the Section 404 program is to insure that the chemical and biological integrity of water in the United States is protected from unregulated discharges of dredged or fill material that could permanently alter or destroy the character of thes invaluable natural resources. The Army Corp of Engineers is the lead agency in enforcing this act. Assisting the Corps in protecting wetlands are several other Federal agencies including the U.S. Forest Service, U.S Bureau of Land Management, U.S. Soil Conservation Service, U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, U.S. Geological Survey and the U.S. Environmental Protection Agency. Violators of Section 404 of the Federal Clean Water Act could be face fines of up to $50,000 per day and/or imprisonment.

On the state and local levels, some states have designated particular stream segments as anti-degradation segments. The protection of these stream segments means the precluding of any discharge of any new point source pollution (i.e. storm runoff, or other pipe conveyance). This makes it mandatory that all new discharges be impounded and erosion controls be implemented to reduce runoff volume and velocity.

In all situations where riparian zones and wetlands are near construction and well drilling activities, it is best to keep disturbance to a minimum. In addition to the well documented ecological problems associated with their abuse, these areas pose some unique problems to development including:

1. Soft or sinking footings
2. Shrink swell soils
3. Periodic inundation - even though they may seem dry during construction
4. Corrosion
5. Water seepage in buried pipe joints

6. Filling or drainage wetlands or wet meadows may disrupt the hydrologic balance down hill or down stream.

In the event drilling or construction in a wetland or near riparian zone is unavoidable:

1. Be sure to contact the proper agencies governing the property upon which the work is to be done. (i.e. Bureau of Land Management, Forest Service, Soil Conservation Service when working on private lands, and the appropriate state department when working on State lands).

2. Contact the U.S. Army Corps of Engineers to determine if a Section 404 permit is required.

3. Contact State or local Water Quality agency to determine if construction is near an anti-degradation segment and what, if any, constraints are required.

When it becomes necessary to drill or construct near riparian zones and wetlands a few best management practices apply:

1. Determine the stream environment zone (SEZ). This is defined as that region 1) which surrounds a stream, including major streams, minor streams and drainage ways which owes its biological and physical characteristics to the presence of water; 2) which may be inundated by a stream; or 3) in which actions of man or nature may directly or indirectly affect the stream. A stream includes small lakes, ponds, and marshy areas through which the stream flows.

2. Determine the minimum buffer strip for the particular stream segment or wetland. This is defined as "a strip of land containing the stream or drainage channel (or wetland) and a designated width of land which is considered the minimum width necessary to protect the integrity of the various characteristics of the SEZ.

3. No structure should be located within the minimum buffer strip for the stream.

4. When the entire parcel lies inside the SEZ, the disturbance should occur on the one best site and should include consideration of drainage, access, soil type, vegetation, hydrological characteristics, elevation, topography and distance from the natural stream channel.

5. When a parcel lies partially within and partially outside of the stream environment zone, the construction site should to the maximum degree possible occupy the portion outside of the stream zone. The foundation should not intrude into nor should any portion of the structure or ground coverage intrude into the SEZ.

6. Filling or draining wetlands or wet meadows may disrupt the hydrologic balance down hill or down stream.

In the event drilling or construction in a wetland or near riparian zone is unavoidable.

1. Be sure to contact the proper agencies governing the property upon which the work is to be done. (i.e. Bureau of Land Management, Forest Service, Soil Conservation Service when working on private lands, and the appropriate state department when working on State lands).

2. Contact the U.S. Army Corps of Engineers to determine if a Section 404 permit is required.

3. Contact State or local Water Quality agency to determine if construction is near an anti-degradation segment and what, if any, constraints are required.

When it becomes necessary to drill or construct near riparian zones and wetlands a few best management practices apply:

1. Determine the stream environment zone (SEZ). This is defined as that region 1) which surrounds a stream, including major streams, minor streams and drainage ways which owes its biological and physical characteristics to the presence of water; 2) which may be inundated by a stream; or 3) in which actions of man or nature may directly or indirectly affect the stream. A stream includes small lakes, ponds, and marshy areas through which the stream flows.

2. Determine the minimum buffer strip for the particular stream segment or wetland. This is defined as "a strip of land containing the stream or drainage channel (or wetland) and a designated width of land which is considered the minimum width necessary to protect the integrity of the various characteristics of the SEZ.

3. No structure should be located within the minimum buffer strip for the stream.

4. When the entire parcel lies inside the SEZ, the distinction should occur on the one best site and should include consideration of drainage, access, soil type, vegetation, hydrological characteristics, elevation, topography and distance from the natural stream channel.

5. When a parcel lies partially within and partially outside of the stream environment zone, the construction site should to the maximum degree possible occupy the portion outside of the stream zone. The foundation should not intrude into nor should any portion of the structure or ground coverage intrude into the SEZ.

6. Above-ground structures should allow peak surface water flows from a 100-year flood to pass with no significant impediment.

7. All foundation of such structures should consist of pier or single-span and should be supported on abutments outside the SEZ, which should not interfere with the passage of a 100-year flood. If single spans are not possible, pier foundations could be utilized.

8. No structure should interrupt the flow of groundwaters within a SEZ. Foundations should be situated with the long axis of uninterrupted impermeable vertical surface oriented parallel to the groundwater flow direction.

The following practices should be utilized to minimize the impact of construction activities in the SEZ:

1. The construction site boundary should be defined in the construction plan and staked on the construction site.

2. Removal of vegetation, compaction of soil, and grading should be minimized. No earth movement, stockpiling, traffic, or clearing should be allowed outside the construction site boundary.

3. Excavated materials and construction materials should be stored within the perimeter of the construction site boundary.

The following mitigation measures should be utilized to reduce the impact of construction activities in SEZ:

1. If standing or flowing surface water exists on the site, no construction may commence until the site is naturally dry and stable. No artifical drainage or diversions are allowed to speed this drying process.

2. Appropriate erosion sediment practices, including applicable temporary runoff management facilities, temporary soil stabilization techniques, and drainage facilities must be used to contain all runoff waters generated on the site, and to prevent high flow waters in the SEZ from entering the construction site. The design and installation of these facilities must be conducted with extreme caution to prevent unintended damage to the SEZ, as through channelization of high flow and acceleration of channel erosion.

3. Rehabiliation and cleanup of the site following construction must include:

   Removal of all construction wastes and debris

   Restoration of natural topography (as far as possible).

Revegetation of all disturbed sites and native plants, especially riparian, meadow, and marsh types.

Periodic inspection and maintenance to assure the rapid naturalization of the disturbed areas.

Specific techniques for the reclaiming of riparian zones and wetlands depend on the purpose for which the site is being reclaimed and the extent of the damage to be, or that has been, caused. There are several technical reports available and these should be consulted if avoidance of wetlands is not possible (US Army Environmental Laboratory 1977; Garvisch 1977 and Thronson 1979).

Where natural wetlands are present, or they can be constructed, there is a unique opportunity to utilize these resource to good advantage. As mentioned above, wetlands can be utilized to aid in solving pollution problems with respect to National Pollutant Discharge and Elimination System (NPDES) permits required by the EPA and at the same time enhance important wildlife habitat.

Stormwater and snow melt runoff can be directed to flow through a wetland which in turn will remove much of the pollution. More research needs to be done to determine how many acres of wetland and what kind of wetlands are required to treat the runoff from an acre of land disturbed by drilling operations.

Extreme caution should be exercised however, Be sure to remove all sediment through sediment ponds or traps before allowing the water to reach the wetland. Also do not allow hydrocarbons, toxic and hazardous materials to reach the wetland. Such substances can cause irreparable harm to the environment.

ECONOMIC CONSIDERATIONS

Costs for reclamation can vary widely from site to site. Although less earthworking is necessary for oil and gas development than strip mining, earth moving costs still play a major role in total reclamation costs. Unlike strip mining, soil removal is not necessary for retrieval of the resource, consequently most earthworking costs must be charged to reclamation. Since earth moving costs are the largest component of reclamation costs, factors that influence the amount and nature of topsoil stripping, replacement, distance of haul and the degree of backfilling and grading required will greatly affect the total cost of reclamation.

Costs that are fairly typical for the type of reclamation occurring in the Bear River Divide region were compiled from the published literature (Kerr Associates, Inc, 1983; Robert Snow Means Company Inc, 1984) and modified from personal contact with operators, contractors, and government agencies (Table 6) for the Bear River region. These costs are general and should be used as relative guides to compare the cost of a technique relative to another technique rather than as absolute costs. Reclamation procedures which are apt to be most commonly used have been selected. Costs for each technique vary widely depending on a number of factors and the costs reported here are ranges of fairly typical costs. General factors that may influence costs include size and contiguous nature of the disturbance, ease of access, type of equipment used, remoteness, steepness of slope, timing constraints, weather conditions, unique implementations or modifications of standard techniques and reliability and performance quality of the contractor.

Reclamation on contiguous areas can occur more rapidly than on small broken or intermittent areas, thus operating expenses and labor cost on a per unit basis are reduced. Mobilization costs in remote areas are often fairly high. Different equipment, capable of accomplishing similar tasks, function with varying degrees of efficiency under different conditions. In addition this equipment often differs in the purchase price and in operation, maintenance and mobilization costs. Some of the costs associated with techniques that should be considered when selecting a technique have been included under the section that the technique is discussed.

Equipment may affect the cost of seeding. Seeding with clean, large seed may be accomplished cheaper by a less expensive farm grain drill, but trashy or variable-sized seed may require a more expensive Brillion or a rangeland drill with seed pickers and multiple seed boxes. Often, factors such as ease of access, slope steepness, weather conditions or unique implementation of reclamation procedures not only delay the reclamation process, thus increasing operating and labor costs, but may necessitate special adapted equipment which in turn increases the costs. Steeper grades often necessitate more expensive techniques or can require more care in traversing the slope, thus increasing the cost. Techniques that have a greater risk of failure may require touch-up work on occasion which increases the cost of that technique. Quality in contractors or materials should not be overlooked since this can greatly affect the usefulness of the technique. Failure from shoddy application does not indicate a faulty technique. Volume purchases and availability of materials can influence

costs. Other specific factors influencing costs have been noted in Table 6. It should be noted that these influencing factors may result in costs outside the ranges listed in Table 6.

In order to evaluate the effectiveness of each dollar spent on reclamation, a cost-benefit analysis should be conducted. This weighs the costs against the returns. Accurate costs as well as site-specific returns are necessary in order to perform a meaningful analysis.

Many different methods exist to account for different costs. Check with your accounting department for an approach that fits in with how your records are kept. The difference between these methods is not as important as the fact that all costs are accounted for, including those costs that may be "hidden". Direct costs which include materials and labor are fairly straight-forward. Material costs will include items such as plant materials, mulch, and fertilizer. Shipping and handling costs should be included. Labor costs include the implementation labor and supervisory labor. Time spent by employees of the operator to oversee subcontracts should be included, although this may be included as an overhead item. Depreciation on equipment owned by the operator as well as operating costs to run the equipment should be determined. Often, contracting costs are on an area basis (e.g. Seeding $80/acre) and sometimes plant and seed materials are included in these figures. The level of specificity of your cost records will affect the level of your analysis. For example: If a contractor provides seeding services at a rate of $120/acre (seed included), it is impossible to compare the cost of establishing different shrub species unless a breakdown of seed mix costs is given on a species basis. Of course for comparative purposes you could request another bid from the contractor using an alternate seed mix.

Indirect costs are often more obscure. These include overhead (rent, utilities, office supplies, transportation, some equipment) and administration (support staff) costs necessary to handle subcontracts and reclamation personnel and/or operations. Other indirect costs include the cost of money and risk. When reclamation alternatives vary greatly in timing of implementation, the cost of money must be accounted for. The cost of money is related to the difference between the prime lending rate and inflation rate and represents interest income over and above the inflation rate lost through time. Accounting for risk enables two techniques to be compared which have different probabilities of success.

In reclamation, a cost-benefit analysis is less straight-forward since it is difficult to put dollar values on reclamation returns. Monetary returns (gross receipts) from the sale of the oil and gas express returns in dollars. Since costs are also defined in dollars a direct comparison between costs and returns could be easily understood and a direct evaluation of an investment could be made. However, these returns are not directly affected by changes in reclamation procedures, except at a threshold, all-or-none level (the right to remove oil and gas) and therefore are not sensitive enough to provide very much utility in analyzing different reclamation procedures. This analysis encourages the over-simplied notion that because reclamation is a cost, the least expensive techniques are the most cost effective.

Biological returns (stems/acre, lbs./acre) are responsive to changes in reclamation procedures and are easily understood by reclamation specialists. Meaningful biological returns, those which the technique is supposed to improve, can be selected for analysis. However, since these returns are in units other than dollars, these returns usually have no direct intrinsic value to the operator. Even the indirect value of these returns fluctuate with the operator. In addition, cost-benefit analyses may not yield a technique that achieves a performance standard. These problems can best be illustrated by examples. Erosion control techniques can be compared as tons of soil/acre lost for each dollar spent in order to evaluate the efficiency of the investment. However, unless performance criteria or the value of public relations is connected with this parameter, it generally has no intrinsic value to the operator. If there is a performance level required, a straight cost-benefit analysis based only on tons of soil/acres lost per dollar spent basis may yield a technique which can never provide the success to satisfy the performance criteria.

Therefore, biological values should be considered in light of their value to the company such as meeting a performance level required by the regulatory agency or the value of the public relations. It might be argued that the technique to be used is the least expensive technique that will meet the performance criteria. The simplicity of this statement is misleading because of the 'unknowns' associated with the determination of whether a technique will achieve a satisfactory performance level. Because there are so many unknowns in the environment (i.e. when, where, how much, what intensity will precipitation occur) biological returns are based on probabilities. This realization illustrates the value of overachievement which is to minimize the risk of failure. This manual has attempted to select those techniques which are more cost-effective while considering their probability of success. The determination of the probability of success has come from the literature and our own experience in the area and with reclamation practices. For example, recent success has been achieved from summer seeding because of the higher than normal precipitation. This technique is not recommended as a general practice because long term precipitation records suggest a higher probability of failure.

Regardless of the complexity of any analysis, results from it are no better than the data input into the analysis. This type of analysis requires both careful and accurate evaluation of costs and success. Site specific results will generate the most reliable analysis. In reclamation, costs are all-important to upper level management. The rewards from carefully evaluating costs and success will help the reclamation specialists or biologists to provide the information needed to implement truly cost-effective reclamation techniques.

Table 6. Ranges of costs and major factors influencing cost often incurred for common revegetation practices. The most typical costs are enclosed in parenthesis. All costs are in 1984 U.S. dollars.

TECHNIQUE	RATE	MAJOR INFLUENCING FACTORS
Site Preparation		
Brush removal (small-med shrubs)	75-200/a	Density and size of woody plants
Topsoil removal & stockpiling (<1/5 mi. haul)	.65-2.5/yd^3 (.9-1.2/yd^3)	Depth of topsoil distance of haul equipment used
Ripping	30-170/a	Depth of ripping, substrate
Topsoil replacement of grading (<1/5 mi. haul)	80-3.00/yd^3 (1.0-1.5/yd^3)	Depth of topsoil, distance of haul, equipment used
Disking	25-50/a (35)	Depth of disking, substrate
Harrowing	20-50/a (30)	Substrate
Slope chaining	100-150/a (125)	Substrate, length of slope
Soil Amendments		
Broadcast Fertilizer	25-60/a (35)	
Ammonium nitrate (34-0-0)	.15-20/lb	
Ammonium phosphate (16-20-0)	.15-.20/lb	
Slow Release tablet (20-10-5)	.08/ea	
Seeding		
Broadcast	20-60/a (35)	
Drill Seed	30-130/a	Amount of trashy seed, grade
Hydroseed	75-250/a	Distance to water length and accessibility of slope
Grass seed (PLS lb)	.90-40/lb (1.5-9/lb)	Species
Forb seed (PLS lb)	.70-50/lb	Species
Shrub seed (PLS lb)	6-110/lb	Species
Planting		
Planting	.30-1.0/ea	Substrate, plant material
Bareroot	.15-.50/ea	Size of plant
Container (tubeling)	.60-.95/ea	Size of plant

Table 6. Continued

TECHNIQUE	RATE	MAJOR INFLUENCING FACTORS
Mulching (Continued)		
Straw/hay blowing	100-200/a	Wind, length of slope, quality mulch material
Crimping	25-45/a	
Hydromulching	75-250/a	Distance to water, length of slope
Excelsior application	900-1800/a	Length of slope
Plastic mesh application	800/a	Length of slope
Straw or hay	60-100/T	Quality, freight, handling
Excelsior	2000/4300/a	Freight, handling
Plastic mesh	2800-2900/a	
Fiber mulch w/ tackifier	.20-1.30/lb	
Fiber mulch w/o tackifier	.20-1.00/lb	
Erosion Control Feature		
Diverson trench	5-7 ft.	
Riprap	16-24/yd^3	Substrate
Mobilization	80-190/ea equipment item	

CONTRACT SPECIFICATIONS

Specifications are written instructions which formulate the precise method or technical requirements of the work. They also define the quality of materials and workmanship and serve as a standard or guide for the contractor. Construction drawings usually show what is to be done and where; whereas the specifications state how the work is to be accomplished. The combination of the drawings and specifications should define completely the physical and technical characteristics of the finished project. Since the specifications and drawings completely describe the work, the document should be logical and comprehensive. Otherwise there may be omissions, conflicting statements and legal disputes. All work and materials desired by the owner must be contained in the specification.

Specification writers need to be familiar with the project area. Soil characteristics, area topography, slopes, access to the site, and acreage should be provided to all prospective bidders. Detailed information contained in the specification allows prospective contractors a more competitive bid by not having to bid the unknown. A site visit by prospective contractors is also important to ensure that the bid is accurate. Once the contract is awarded, contractor-owner disputes can be minimized because both parties have a better understanding of the site conditions.

Reclamation specification writers should be familar with revegetation techniques to be used in a particular area. Too often the revegetation of semi-arid native areas and turf grass areas are written with the same specifications. As noted in the reclamation matrix, the revegetation of steep slopes and flatter areas require different techniques which should be stated in the specification. If bids are requested from contractors with a good reputation it may be advantageous to let the contractor suggest modifications subject to approval by the reclamation specialist.

The specification should define which materials are to be used. The writer should know material availability and costs. Some varieties of native plant seed may be overly expensive or unavailable. Hay and straw may be difficult to obtain or may be unavailable during the spring and by letting a contract early in the fall for spring work hay or straw can be secured and eliminate the problem. Checking with suppliers as to availability and cost prevents rebidding, addendums, and confusion.

Specifications for materials should include details on the acceptable quality of the materials, delivery locatins and time, storage pile specifications and should define the responsibility of unloading the materials. The weights upon which payment is based should be clearly defined also. Specifics on acceptable materials have been included under the appropriate sections of the manual.

Specifications should be organized in a logical sequence. This will not only help the writer by preventing discrepancies and deletions but will also help the contractor in his organization and ordering materials. An example of one method to organize a technical section is given below:

B. Seeding

1. Where

2. Materials
   a. seed mix and rates

3. Submittals
   a. state seed lab certification

4. Methods
   a. drill
   b. broadcast

5. Cleanup

Some specifications have required a guarantee on the work such as plant area cover or density, transplant survival, or securing netting. Guarantees should be weighed carefully before they become part of the contract specification. Although the quality of work can be guaranteed, revegetation success is dependent on factors beyond the control of the contractor. Unpredictable, dry weather, for example, may negate the best technique. Many contractors are unwilling to risk the uncertainty of guaranteeing good establishment and will double their bid price so that they are covered in case of a failure. Therefore, the operator pays for failure even if it does not occur. It would probably be more economical to wait a growing season and rebid any needed touchup work. Given that proper revegetation techniques have been specified, conditional guarantees based on the environmental conditions during germination and growing season are a better way to guarantee good workmanship without burdening the contractor with unknown physical and climatic conditions.

Contractor compensation or payment is also part of the specifications. Generally, payment is specified in per acre unit prices rather than lump sum payment. The method of determining area measurement should be stated in the contract specification. Most drill seeders are equipped with acre meters which when calibrated, provide accurate acre measurement and also allow the contractor to determine accurate seeding rates. Acreage in the specifications and drill seeder acre meters should be checked for accuracy. Materials are purchased based on the projected disturbance size. If the owner states that an area is 10 acres when the area is really 20 acres, then only half the specified material might be applied.

The contractor's qualifications and experience should be carefully considered when selecting a contractor and the project time table should allow sufficient time for top contracting firms to schedule in advance. Important qualifications that should be considered are: 1) state licensing, 2) bonding, 3) physical equipment available for the task, 4) fiscal capability to handle the project, 5) construction background, 6) educational background, and 7) member of appropriate professional societies and associations. In considering the experience of the contracts, the following should be evaluated: 1) past experience in the specialties involved, 2) magnitude or scale of prior contracts, 3) past track record, 4) whether key personnel are knowledgeable in the technical aspects of the

contract and 5) safety history. These factors can be weighted as to their relative importance for each job and a score sheet developed to aid in selection of the contractor.

Summary

SUMMARY

Techniques have been recommended in this manual to assist reclamation efforts in ultimately reestablishing wildlife habitat. Each section has attempted to emphasize the reclamation of land disturbed by oil and gas activities for the ultimate purpose of reconstructing useful wildlife habitat, primarily big-game habitat. The short-term objectives have been to stabilize the disturbed site and control soil erosion in order to conserve the important soil resources and prevent offsite deterioration of adjacent wildlife habitats. The long-term objective has been to reestablish important plant species in the proper composition, spacing and quality so as to provide useful wildlife habitat while at the same time protecting the integrity of the site from further degradation.

Discussions in each appropriate section have focused on these objectives. Several additional techniques are believed to be important in accelerating the development of wildlife habitat over and above those reclamation techniques required to control soil erosion and ensure site integrity. These additional techniques include:

- Avoidance of key wildlife habitat areas
- Minimizing the size and degree of disturbance
- Use of supplemental seed mixes that help augment the reestablishment of key browse species
- Use of unseeded strips of ground that encourage natural colonization by desirable browse species
- Enhancing reestablishment of selected shrub species by the use of transplant materials
- Monitoring site conditions for special problems and effectiveness of reclamation techniques

These techniques have been discussed in more detail under the appropriate sections. Selection of one or more of these techniques should be based on the ultimate land use objectives established for each specific site and the need to accelerate the reestablishment of the wildlife habitat considering such landuse objectives in the context of development activities on adjacent lands and the ability of adjacent wildlife habitat to fill the needs of resident wildlife.

It is anticipated that better reclamation techniques will be discovered and developed in the future to help increase the effectiveness of the reestablishment process. Several of these techniques are currently being used, but will require more testing and evaluation before they can be recommended for general use. Further research is required in the following areas:

- Determination of germination requirements for key plant species that comprise selected wildlife habitats

- Testing and evaluation of direct seeding techniques to encourage key plant species that comprise selected wildlife habitats

- Identification and testing of techniques for encouraging natural colonization by desireable plant species

- Investigate the effectiveness of selected weed-control techniques

Many of these research areas are of concern to other industries in the West. These areas of concern will likely receive increased emphasis for future research, however, it is anticipated that funding will likely be limiting in all sectors of private industry, educational institutions, and government due to recent national economic trends. Significant efficiencies will likely occur through the use of cooperative research efforts such as those developed as part of the Cooperative Wildlife Program, as sponsored by the Overthrust Industrial Association. Our knowledge base will be expanded and facilitated through the cooperative sharing of information and ideas.

The development and distribution of this manual is made possible through the efforts of numerous individuals that have demonstrated their concern and interest in the preservation of our wildlife resources and concurrent development of our mineral and petroleum resources. These efforts will hopefully serve as a stepping stone to increased cooperation and communication among those responsible for developing and managing our natural resources in the Bear River Divide region.

Literature Cited

LITERATURE CITED

Amimoto, P.Y., Erosion Sediment Control Handbook, California Department of Conservation and EPA, Washington, D.C. May 1978, p. 196.

Garvisch, E.W. 1977. Recent and planned marsh establishment work throughout contiguous U.S. - a survey and basic guidelines. U.S. Army Environmental Laboratory, Engineer Waterways Exp. Stn., Vicksburg, Miss. #D-77-3.

Kerr Associates, Inc. 1983 Cost Data for Landscape Construction Colwell Press Inc., Minneapolis, MN.

May, M.R., Lang, L., Lujan, P., Jackoby, and W. Thompson. 1971. Reclamation of strip mine spoil banks in Wyoming. Wyoming Agric. Exp. Stat. Res. Jour. 51. 32 p.

NPI, 1983. Vegetation resource monitoring and reclamation research: Final report for White River Shale Oil Corporation, NPI, Salt Lake City, Utah.

OIA, 1985. Cooperative Wildlife Program Appendices to Reclamation Manual: Appendix I, A survey of existing literature and information; Appendix II, Analyses of Success and Cost Effectiveness of Reclamation Practices.

OIA, in press. Cooperative Wildlife Program: Wildlife Habitat Maps

Public Law 95-217 (Dec. 27, 1977), Clean Water Act of 1977, 91 STAT,1566.

Robert Snow Means Company. 1984. Means Site Work Cost Data. Robert Snow Company, Inc., Kingston, Maryland.

Salt Lake County. 1981. Erosion - Sediment Control Handbook. Salt Lake County Water Quality and Pollution Control Publication, Salt Lake County, Utah.

Sindelar, B.W., R.L. Hodder, and M.E. Majerus. 1973. Surfaced mine land reclamation research in Montana. Montana Agric. Exp. Stat. Res. Rep. 40. 122 p.

Skelly and Loy Engineering Consultants. 1975. Economic Engineering Analysis of U.S. Surface Coal Mines and Effective Land Reclamation. U.S. Bureau of Mines Report, 50-241049.

LITERATURE CITED

Smith, R. 1981. The effects of mulches and fertilizer on vegetation establishment in southwestern Wyoming. In: Shrub Establishment on Disturbed Arid and Semi-arid Lands, Proceedings of the Symposium held in Laramie, Wyoming. December 2-3, 1980. Wyoming Game and Fish Department.

Tahoe Regional Planning Agency. 1978. Handbook of best management practices, Vol. Ii. Lake Tahoe Basin Water Management Plan.

Thronson, R.E. 1971. Control of Sediments Resulting from Highway Construction and Land Development, EPA Washington, D.C.

Thronson, R.E. 1979. Best management practices guidance, discharge of dredged or fill materials. U.S.-EPA Office of Water Planning and Standards, Washington, D.C. EPA 440/3-79-028.

U.S. Army Environmental Laboratory. 1978. Wetland habitat development with dredged material: engineering and plant propagation. Engineer Waterways Exp. Stn. Vicksburg, Miss. #DS-78-16.

U.S.D.A Soil Conservation. 1975. Standards and specifications for soil and sediment control in developing areas, College Park, Maryland.

U.S.D.I. Bureau of Land Management, U.S.D.A. Geological Survey and U.S.D.A. Forest Service, 1977.

U.S.D.I. Bureau of Land Management U.S.D.I. Geological Survey and U.S.D.A Forest Service, 1977. Oil and gas - surface operating standards for oil and gas exploration and development.

U.S.D.I Bureau of Land Management. 1981. BLM Draft 1737 Fencing Manual, 1-22.

Vallentine, J.R. 1980. Range Development and Improvements. 2nd Ed. Brigham Young University Press, Provo, Utah 516 pp.

Van Epps, G.A. and McKell, C.M. 1980. Revegetation of disturbed sites in the salt desert range of the Intermountain West. Utah Agri. Exp. Stn. Land Rehab. Series No. 5. 54 pp.

Wyoming Department Environment Quality, 1984. Guideline No. 1 Topsoil and Overburden. Wyoming, DEQ, Cheyenne, Wyoming.

Appendicies

Appendix A. List of common names and their accompanying scientific names.

Grasses

Alkali sacaton	*Sporobolus airoides*
Alti wildrye	*Elymus angustus*
Basin wildrye	*Elymus cinereus*
Bluebunch wheatgrass	*Agropyron spicatum*
Cheatgrass	*Bromus tectorum*
Columbia needlegrass	*Stipa columbiana*
Crested wheatgrass	*Agropyron desertorum*
Green needlegrass	*Stipa viridula*
Hard sheep fescue	*Festuca ovina duriuscula*
Indian ricegrass	*Oryzopsis hymenoides*
Intermediate wheatgrass	*Agropyron intermedium*
Kentucy bluegrass	*Poa pratensis*
Mountain brome	*Bromus marginatus*
Mutton bluegrass	*Poa fendleriana*
Orchard grass	*Dactylis glomerata*
Pubescent wheatgrass	*Agropyron trichophorum*
Russian wildrye	*Elymus junceus*
Siberian wheatgrass	*Agropyron sibericum*
Sheep fescue	*Festuca ovina*
Slender wheatgrass	*Agropyron trachycaulum*
Squirrel tail	*Sitanian hystrix*
Streambank wheatgrass	*Agropyron riparium*
Thickspike wheatgrass	*Agropyron dasystachyum*
Timothy	*Phleum pratense*
Western wheatgrass	*Agropyron smithii*

Forbs

Alfalfa	Medicago sativa
Arrowleaf balsamroot	Balsamorhiza sagittata
Birdsfoot deervetch	Lotus corniculatus
Canadian thistle	Cirsium arvense
Cicer milkvetch	Astragalus cicer
Dyer's woad	Isatis tinctoria
Halogeton	Halogeton glomeratus
Henbane	Hyoscyamus niger
Knotweed	Polygonum viviporum
Lewis flax	Linum lewisii
Musk thistle	Carduus nutans
Palmer penstemon	Penstemon palmeri
Pennycress	Thlaspi arvense
Pigweed	Chenopodium album
Rocky mountain penstemon	Penstemon strictus
Russian thistle	Salsola pestifer
Sainfoin	Onobrychis viciaefolia
Small burnet	Sanquisorba minor
Sulfur buckwheat	Eriogonum umbellatum
Utah sweetvetch	Hedysarum boreale germinale
Wild geranium	Geranium fremontii
Yarrow	Achillea millefolium
Yellow sweetclover	Meliotus officinalis

Shrubs

Antelope bitterbrush	Purshia tridentata
Gardner saltbush	Atriplex gardneri
Nuttall saltbush	Atriplex nuttallii
Prostrate summer cyprus	Kochia prostrata
Russian olive	Forestiera neomexicana
Serviceberry	Amelanchier alnifolia
Shadscale	Atriplex confertifolia
Siberian peashrub	Caragana arborescens
Snowberry	Symphoricarpos oreophilus
White rubber rabbitbrush	Chrysothamnus nauseosus albinicaulis
Winterfat	Ceratoides lanata
Woods rose	Rosa woodsii
Wyoming sagebrush	Artemesia tridentata wyomingensis

Appendix B. SNOW CONTROL WITH ROAD DESIGN AND SNOW FENCES[1]

Ronald D. Tabler[2]

I. ROADS CAN BE DESIGNED TO PREVENT DRIFTS

A. Snowdrift profiles can be predicted from topographic data using the empirically derived regression equation

$$Y = 0.25X_1 + 0.55X_2 + 0.15X_3 + 0.05X_4$$

(if measured X_2, X_3, X_4, < -20, set X_2, X_3, X_4 = -20)

where Y is the snow slope (%) over the main portion of the drift, X_1 is the average ground slope (%) over a distance of 45m (150 ft) upwind of the catchment, and X_2, X_3, and X_4 are the ground slopes (%) over distances of 0-15m (0-50 ft), 15-30m (50-100 ft), and 30-45m (100-150 ft) downwind of the trap lip. Slopes upward in the direction of the wind are taken as positive, and downward slopes as negative. A dynamic extension of this method can be used to predict the snow slope at any point on a drift, thus allowing snow profiles to be constructed across a highway cross-section or natural terrain transects extending for long distances. More detailed information, and a program listing for the Hewlett-Packard 9820A calculator, is given in the following reference:

Reference: Tabler, Ronald D. 1975. Predicting profiles of snowdrifts in topographic catchments. Proc. Western Snow Conf. 43: 87-97.

B. The Wyoming State Highway Department is using this snowdrift prediction technique for road design (snowdrift prediction model is included as option in earthwork computer program).

For further information, contact Mr. Donald Carlson, State Highway Development Engineer, Wyoming State Highway Department, P.O. Box 1708, Cheyenne, WY 82001 (Phone: 307-777-7487).

C. "Box-beam" guardrail should be used in preference to "corrugated-beam" guardrail. Concrete median barriers should be used only where necessary.

Reference: Tabler, Ronald D. and Robert L. Jairell. 1980. Studying snowdrifting problems with small-scale models outdoors. Western Snow Conference Proceedings 48:1-13.

---

[1]Outline of presentation at the Snow Removal and Ice Control Technical Institute, University of Wisconsin--Extension, Madison, WI, October 13-14, 1981.

[2]Research Hydrologist, Rocky Mountain Forest and Range Experiment Station (Forest Service, USDA), 222 South 22nd Street, Laramie, WY 82070.

II. SNOW FENCES PREVENT DRIFTS, IMPROVE VISIBILITY, AND REDUCE ROAD ICE

A. Properly designed snow fence systems eliminate drifts in road cuts and reduce snow removal expenditures.

Snow fences prevent drift formation by trapping snow upwind of the protected area, and by inducing erosion of snow within the protected area. The effect of removing snow particles from the wind is analogous to that of a dam on a sediment-laden river. Just as clear water released from a reservoir has increased eroding capability, snow-free wind tends to erode snow from a protected road cut.

A $2,000,000 snow fence system on Wyoming Interstate-80, eliminated drifts and reduced snow removal costs by more than one-third.

References:

1. Tabler, Ronald D. and Richard P. Furnish. 1982. Benefits and costs of snow fences on Wyoming Interstate 80. Transportation Research Record 860. p. 13-20. National Academy of Sciences, Washington, D.C.

2. Tabler, Ronald D. 1973. New snow fence design controls drifts, improves visibility, reduces road ice. Annual Transp. Eng. Conf. (Colo. Univ., Denver, Feb. 1973) Proc. 46:16-27.

B. Snow fences can reduce accidents. Snow fence protection along a 100-km section of Wyoming Interstate-80 has gradually been increased from 0% in 1970, to 51% in 1980. An 11-year study of the accidents on this section of highway showed that accidents during blowing snow conditions decreased in proportion to the length of highway protected, with a 70% reduction at the present level of fencing. There is some indication of a comparable reduction in wind-related accidents. These effects reflect the improved visibility and road surface conditions observed in the areas protected by snow fences.

References:

1. Tabler, Ronald D. and Richard P. Furnish. 1982. Benefits and costs of snow fences on Wyoming Interstate 80. Transportation Research Record 860. p. 13-20. National Academy of Sciences, Washington, D.C.

2. Tabler, Ronald D. 1973. New snow fence design controls drifts, improves visibility, reduces road ice. Annual Transp. Eng. Conf. (Colo. Univ., Denver, Feb. 1973) Proc. 46:16-27.

C. Fence construction costs can be amortized within 10 years through reduced winter maintenance costs and property damage.

Reference:

1. Tabler, Ronald D. and Richard P. Furnish. 1982. Benefits and costs of snow fences on Wyoming Interstate 80. Transportation Research Record 860. p. 13-20. National Academy of Sciences, Washington, D.C.

III. REQUIREMENTS FOR SUCCESSFUL SNOW FENCE SYSTEMS

A. Fence systems must have <u>adequate capacity</u>.

1. Estimating snow transport using concept of transport distance and in-transit evaporation:

Snow transport water-equivalent (Q_T, ft^3 H_2O/ft) can be estimated from

$$Q_T = 5000\ P_r \left(1 - 0.14^{0.0001R} \right)$$

where P_r is relocated precipitation (ft, water-equivalent) and R is the "fetch" or contributing distance (ft).

Reference: Tabler, Ronald D. 1975. Estimating the transport and evaporation of blowing snow. p. 85-104. <u>In</u>: Snow Manage. on Great Plains Symp. (Bismarck, N. Dak., July, 1975) Proc. Great Plains Agric. Counc. Publ. 73, 186 p.

The appendix contains a procedure for determining the required capacity of snow fence systems.

2. Characteristics of "full" drifts behind the Wyoming Highway Department Standard-Plan fences on level terrain (50% fence porosity):

Drift on windward side of fence:
- Length = 12 H (H = total vertical fence height)
- Maximum depth = 0.5 H
- Location of maximum depth = 0.4 H
- Cross-sectional area = 2.6 H^2
- Profile equation:

$$(Y/H) = 0.5 - 0.04(X/H)$$

where Y = snow depth and X = distance from fence

Drift on leeward side of fence:
- Length = 30 H
- Maximum depth = 1.20 H
- Location of maximum depth = 6.7 H
- Cross-sectional area = 19.3 H^2
- Water-equivalent = 6.9 $H^{2.18}$ (H in m, water-equiv. in m^3/m)
- Profile equation:

$$(Y/H) = 0.20 + 0.377\ (X/H) - 0.0472(X/H)^2 + 0.002329(X/H)^3 - 5.392 \cdot 10^{-5}(X/H)^4 + 4.840 \cdot 10^{-7}(X/H)^5;\ (X/H) \leq 30$$

III. (Continued)

Snow density:

$$d = 376 + 158 \log_{10} D$$

where density, d, is in kg/m^3, and depth D is in m

From the above equation, the density of snow 1 m (328 ft) in depth is 376 kg/m^3 (or 37.6% water), while a 4-m deep drift (13.1 ft) would have a density of 471 kg/m^3, or 47.1% water. The average water content of drifts on the leeward side of fences is therefore

fence height		water content
m	ft	%
1.22	4.0	37
1.83	6.0	40
2.44	8.0	42
3.66	12.0	45

An approximate generalization is that snowdrifts are about 45% water before the onset of melt, and the water-equivalent capacity of the Wyoming Highway Department standard-plan fences is about 10 H^2, taking into account both windward and leeward drifts.

3. Characteristics of "full" drifts behind the typical vertical-slat/ woven wire ("Canadian") fence, erected vertically:

Drift on leeward side of fence:
Length = 26.5 H
Maximum depth = 1.06 H
Location of maximum depth = 5.7 H
Cross-sectional area = 14.5 H^2
Profile equation:

$$(Y/H) = 0.13 + 0.402(X/H) - 0.0602(X/H)^2 + 0.003691(X/H)^3 - 0.00010854(X/H)^4 + 0.0000012495(X/H)^5; \quad (X/H) \leq 26.5$$

Water-equivalent = 5.1 $H^{2.18}$ (H in m, water-equiv. in m^3/m)

The vertical-slate woven wire fence is therefore only about 78% as effective as the Wyoming Highway Department standard-plan fence (based on capacity).

XII. (Continued)

4. Effect of wind orientation on cross-sectional area of lee drift:

Cross-sectional area of a lee drift, measured perpendicular to the fence, decreases as the cosine of the wind departure angle. Geometry of the drift parallel to the wind is independent of the orientation of the fence relative to the wind. Snow storage per unit length of fence is maximized with the fence perpendicular to the prevailing wind.

5. Effect of end of fence on cross-sectional area of lee drift:

The drift near the end of a snow fence is rounded by wind sweeping around the fence. This end effect extends inward as far as 12H from the end of the fence. Cross-sectional area, A, of a drift varies as a function of distance X_e from the end of the fence of height H according to

$$A/A_{max} = 0.23 + 0.192X - 0.0168X^2 + 0.00051X^3$$

where A_{max} is the cross-sectional area in the center of a very long fence, and $X = X_e/H$, $(-1 < X < 13)$.

As an example, the cross-sectional area at 5H from the end of a fence is only about 83% of that at distances more than 12H from the end. This relationship is important for determining minimum overlap of staggered fences, minimum distances fences should be extended beyond the area to be protected, and minimum fence lengths.

6. Geometry of drifts before fences are full:

Maximum depth of the lee drift (D_{max}) is related to degree of saturation S (defined as A_{lee}/A_{max}) according to

$$D_{max}/H = 0.069 + 4.56S - 7.91S^2 + 6.50S^3 - 2.01S^4$$

The length of the lee drift (L) is related to degree of saturation (S) according to

$$L/H = 8.3 + 9.8S + 10.9S^2$$

When a fence is 50% filled, for example, the maximum depth of the lee drift is 1.06H and the length of the lee drift is about 16H.

7. Height and number of rows of snow fence can be determined using the method given in the appendix "How to determine required capacity of snow fence systems.

II. (Continued)

References for Section III.A.:

Tabler, Ronald D. 1974. New engineering criteria for snow fence systems. Transp. Research Board (Nat. Res. Counc.) Transp. Res. Record 506:65-78.

Tabler, Ronald D. 1980. Geometry and density of drifts formed by snow fences. Journal of Glaciology 26(94):405-419.

B. Tall fences should be used in preference to shorter ones.

1. Analysis of data presented by Budd, W., Dingle, R., and Radok, U. (1965. The Byrd snow drift project - outline of basic results. In: Antarctic Research Series, V. 7, Amer. Geophys. Union) shows the following distribution of snow transport with height above the ground surface:

Height above surface		% of total transport in lowest 200 m above sfc.
meters	feet	
wind at 10 m (33 ft) = 11.6 m/s (26 miles/hr)		
0 - 1.22	0 - 4.0	95
0 - 3.66	0 - 12.0	99
wind at 10 m (33 ft) = 22.3 m/s (50 miles/hr)		
0 - 1.22	0 - 4.0	77
0 - 3.66	0 - 12.0	95

From this example, it is obvious that tall fences would intercept an appreciably larger fraction of the total snow transport at the higher wind speeds. This is particularly important where visibility improvement is an objective.

2. Construction cost per unit of snow storage capacity decreases with increasing fence height. For the I-80 snow fence systems, construction cost C (in $ per m^3 of water-equivalent storage) is approximated by

$$C = k + (1.70/H)$$

where H is fence height in meters and

$k = -0.237$ in 1971
$= -0.21$ in 1972
$= +0.02$ in 1974
$= -0.065$ in 1977
$= -0.03$ in 1978

III. (Continued)

Based on the 1978 contract, for example, a fence system comprised of four 1.83-m (6-ft) fences would cost more than twice as much as a single 3.7-m (12-ft) fence having the same capacity.

3. Tall fences require less space than multiple rows of shorter fences having the same total capacity. Easement costs would therefore be expected to be less with taller structures.

   For example, assume minimum fence spacing were 35H from the right-of-way (R/W) and between adjacent rows of fencing. Four 6-ft fences would therefore require a distance of 4 x 35 x 6 = 840 ft, while a single row of 12-ft fence would require only 1 x 35 x 12 = 420 ft. Snow storage capacities would be approximately the same.

4. Tall fences effect a greater reduction in wind speed on the protected roadway (see section II. C.)

C. Optimum fence configuration:

1. Porosity should be approximately 50%
   (general agreement in literature)

2. 15° inclination from vertical, downwind

   The advantage of a slight inclination was first suggested by Finney (Finney, E. A. 1934. Snow control on the highways. Mich. Eng. Exp. Sta. Bul. 57. 62 p). Although we're not certain 15° is the optimum value, this amount of inclination is thought to contribute to the exceptional capacity of the Wyoming Highway Department's standard-plan fence.

3. Bottom gap of at least 0.10H, but no more than 0.15H

   A bottom gap reduces the tendency for snow to deposit at the fence. As a fence becomes buried, its effectiveness seems to be reduced, and structural damage can result, particularly on side slopes. There may be an increased tendency for particles to be lofted over the fence once the bottom gap becomes chocked. The drift behind a fence that is completely buried is significantly shorter than that behind an exposed structure.

4. 6-inch horizontal slats

   Horizontal slats have the definite advantage of retarding deposition at the fence, since the horizontal openings between slats can serve as a bottom gap once the original space between the ground and fence has been filled. Other advantages of horizontal slats include ease of construction and better longitudinal distribution of stress. In our experience, fences made of slats about 6 inches wide performed as well as those 2 inches in width. There is some evidence, however, that performance may be poorer when slat widths exceed about 12 inches.

III. (Continued)

Reference: Tabler, Ronald D. 1974. New engineering criteria for snow fence systems. Transp. Res. Board, Transp. Res. Rec. 506:65-78.

D. Fence length should be as long as possible (never shorter than 30H) and without gaps between panels. See section III.A. 5. and reference given above.

E. Optimum fence placement:

1. Fences should never be placed closer than 30H from the right-of-way if there is any likelihood they will fill. In situations where easements cannot be obtained outside the R/W or where space is limited, use can be made of the geometry of drifts before saturation (section III. A. 6.) to design a tall fence having the required capacity at a stage prior to saturation when the drift would not encroach on the roadway. Effect of terrain on drift geometry should be considered, to increase capacity of the fence and identify the possibility of drift encroachment on the protected area (see reference in section III. C.). This is particularly important where a narrow R/W does not provide an adequate safety margin.

2. Multiple rows of fence should be spaced at least 35H apart, to minimize snow deposition at downwind fences that could cause choking out of the bottom gap and structural damage.

3. Staggered fences should be overlapped at least 10H where the prevailing wind direction is relatively constant. More overlap should be provided where wind direction is variable.

4. Fences should extend at least 10H beyond the area to be protected, as determined from the expected range in wind direction.

5. Fences should be approximately perpendicular to the mean prevailing wind direction for reasons of economy. As described in section III. A. 4., snow storage capacity per unit length of fence decreases as the cosine of the angular departure from perpendicular.

Methods for determining wind direction and fence alinement:

a. Field observation of drifts, abrasion of wood posts, abrasion of rocks, hedging and bending of vegetation, and field measurements of wind direction.

b. Best method is to take several flights of aerial photos during winter months, measure angles of drift features, and plot as chart of wind direction versus milepost.

c. Even where wind direction is relatively constant, assume an angular variation of about 45° (i.e., $\pm$ 22½°) for determining overlap and extension of fences beyond area to be protected.

III. (Continued)

6. Use terrain to increase fence capacity where possible. (Refer to reference following section III. C. 4). Ridge sites may be associated with relatively poor trapping efficiency due to increased tendency for particle lofting.

7. Fences placed at distances up to 100H from the R/W provide adequate protection if their snow storage capacity is sufficient.

IV. WIND LOADS ON SNOW FENCES AND ANCHORAGE SYSTEMS

A. Calculation of wind loads

1. Drag coefficient for 50% porous fence = 1.05

This value was derived from field measurements on the Wyoming Highway Department Standard-Plan Fence.

Reference: Tabler, R. D. 1977. Letter to State Project Development Engineer, Wyoming State Highway Department. January 20, 1977.

2. Taking into account the shape of the wind profile over snow-covered surfaces and using the drag coefficient given above, wind load can be estimated from

$$F/L = 0.268\rho U^2 (H^{1.2} - g^{1.2})$$

where

F/L = force per unit length of fence (newtons/m)
ρ = air density (kg/m^3)
U = Design wind speed at 10-meter height (m/s)
H = Total fence height (m)
g = Bottom gap (m)

(note: To convert from newtons/m to lbf/ft, multiply by 0.0685)

3. Location (above ground) of resultant force on 50% porous fences can be estimated from

$$Z = 0.548 (H^{2.2} - g^{2.2})/(H^{1.2} - g^{1.2})$$

where Z = location of resultant force (m)
and other terms are as previously defined.

4. Air density (ρ) in the wind load equation can be calculated from

$$\rho = \frac{353(1-0.000022569E)^{5.255}}{t + 273}$$

where E = elevation above sea level (m)
t = air temperature (°C)

IV. (Continued)

5. Design criteria used by the Wyoming State Highway Department are:

Minimum air temperature = -23° C (-10° F)
(in Wyoming, strong winds are typically associated with air temperatures above -7° C)

Maximum (gust) wind speed at 10-m (33 ft) height = 54 m/s (120 miles/hr)

B. Anchorage systems

Extraction tests have shown that driven re-bar anchors (#6 x 5' -0") are sufficient for fences up to 3.8 m (12.4 ft) tall, except on wet soils (where a buried deadman is used for fences taller than 2.5 m (8 ft)).

Reference: Wyoming Highway Department Standard Plans.

V. THE I-80 SNOW FENCE SYSTEM

A. History:

1. Section of I-80 between Laramie and Walcott (about 77 miles) was opened to traffic on Oct. 3, 1970, without snow fences.

2. First snow fence contract let in June, 1971 (Cyril Rahonce & Co. of Rock Springs, WY):

6-ft fence:	1376 ft	@ $5.25
8-ft fence:	8496 ft	@ 6.25
10-ft fence:	8672 ft	@ 7.50
12-ft fence:	41760 ft	@ 8.18

Total fence length = 60,304 ft, at a cost of $481,281.

3. Second contract let in September, 1972 (Eagle Construction Co):

8-ft fence:	7104 ft	@ $7.00
12-ft fence:	41024 ft	@ 9.00

Total fence length = 48,128 ft, at a cost of $464,348

4. Third contract let in July, 1974 (Cryril Rahonce & Co.):

8-ft fence:	5712 ft	@ $10.25
12-ft fence:	8224 ft	@ 16.95

Total fence length = 13,936 ft, at a cost of $233,794.

V. (Continued)

5. Fourth contact let in September, 1977 (Orr Construction Co.):

8-ft fence: 12160 ft @ $ 8.90
12-ft fence: 17760 ft @ 14.25

Total fence length = 29,920 ft, at a cost of $416,848.

6. Fifth contract let in May, 1979 (Engineered Structures):

8-ft fence: 8256 ft @ $ 9.50
12-ft fence: 12640 ft @ 15.50 (for standard re-bar anchors; $19.50 for 848 ft of fence for buried deadman anchor)

Total fence length = 20,896 ft, at cost of $313,719.

B. Total system:

6-ft fence:	1376	ft	(1%)
8-ft fence:	41728	ft	(24%)
10-ft fence:	8672	ft	(5%)
12-ft fence:	121408	ft	(70%)
Total fence:	173184	ft	= 32.80 miles

Total cost = $1,909,990.

SNOW CONTROL WORKSHOP

HOW TO DETERMINE REQUIRED CAPACITY OF SNOW FENCE SYSTEMS

R. D. Tabler

I. ESTIMATE AVERAGE WINTER SNOW TRANSPORT (Q_T)

A. By field measurement

1. Measure cross-sectional area (A, ft^2) of snow in cut or natural snow accumulation area that is not completely full (not necessarily the same location for which fences are being designed).

2. Measure "fetch" distance contributing snow to accumulation area (ft).

3. Calculate $Q_T' = 0.45A$ (A in ft^2, Q_T' in ft^3 H_2O/ft). The prime (') is used to distinguish the measured accumulation from the estimate for the fence site. This calculation assumes the snow water-equivalent is 45%.

4. Enter curves (fig. 1) and determine relocated precipitation (P_r), in inches. Adjust this value if measurement year was known to be above or below "normal."

5. Use this value to determine snow transport (Q_T) at fence sites having different fetch distances, using fig. 1.

6. Example: Measure A = 1500 ft^2 and fetch = 5,000 ft. Calculate $Q_T' = 675$ ft^2 H_2O/ft. From fig. 1, relocated precipitation = 2.7 inches. Interpolating 2.7-inch curve in fig. 1 estimated transport for 10,000 ft fetch would be about 975 ft^3/ft. For 2,000 ft fetch, estimated transport (Q_T) = 400 ft^3 H_2O/ft.

7. Go to II.

B. From precipitation data

1. Determine average winter precipitation (P, in inches water-equivalent) from historical records (we use November 1 to April 1 for the winter season at elevations between 7,000 and 9,000 ft in Wyoming).

2. Estimate "relocated" winter precipitation (P_r, in inches water-equivalent) from $P_r = P - 0.35$ (vegetation height).

   Example: if P = 6.0 inches and height of vegetation over fetch distance is 8-inches, $P_r = 6.0 - 0.35(8) = 3.2$ inches.

3. Determine fetch distance (R, ft) contributing snow to fence site.

4. Enter curves (fig. 1) with R and P_r and read snow transport from Y-axis. Example: if P_r = 3.2 inches and R = 10,000 ft, Q_T = 1180 ft^3 H_2O/ft.

II. CALCULATE REQUIRED FENCE HEIGHT (H, ft) from $H = 1/3 \sqrt{Q_T}$

(Derived from $Q_S = 9\ H^2$, where Q_S is the storage capacity (ft^3 H_2O/ft) of a snow fence having height H (ft)).

III. If H as determined in Step II is taller than the maximum standard-plan height (12.4-ft for the Wyoming Highway Department fences), DETERMINE HOW MANY ROWS OF DIFFERENT HEIGHTS WILL BE REQUIRED. Water-equivalent storage capacity (Q_S, ft^3 H_2O/ft) for a fence of height H (ft) is given by $Q_S = 9\ H^2$:

H (ft)	Q_S ($ft^3 H_2O$/ft)
5.0	220
6.0	320
8.0	580
10.4	970
12.4	1380

Example: If estimated snow transport is 2000 ft^3 H_2O/ft, use one row of 12.4-ft fence and one row of 8-ft fence.

IV. REFERENCE

R. D. Tabler. 1975. Estimating the transport and evaporation of blowing snow. Proc. Symp. on Snow Management on the Great Plains (Bismarck, N. Dak., July, 1975), Great Plains Agricultural Council Publ. 73. p. 85-104.

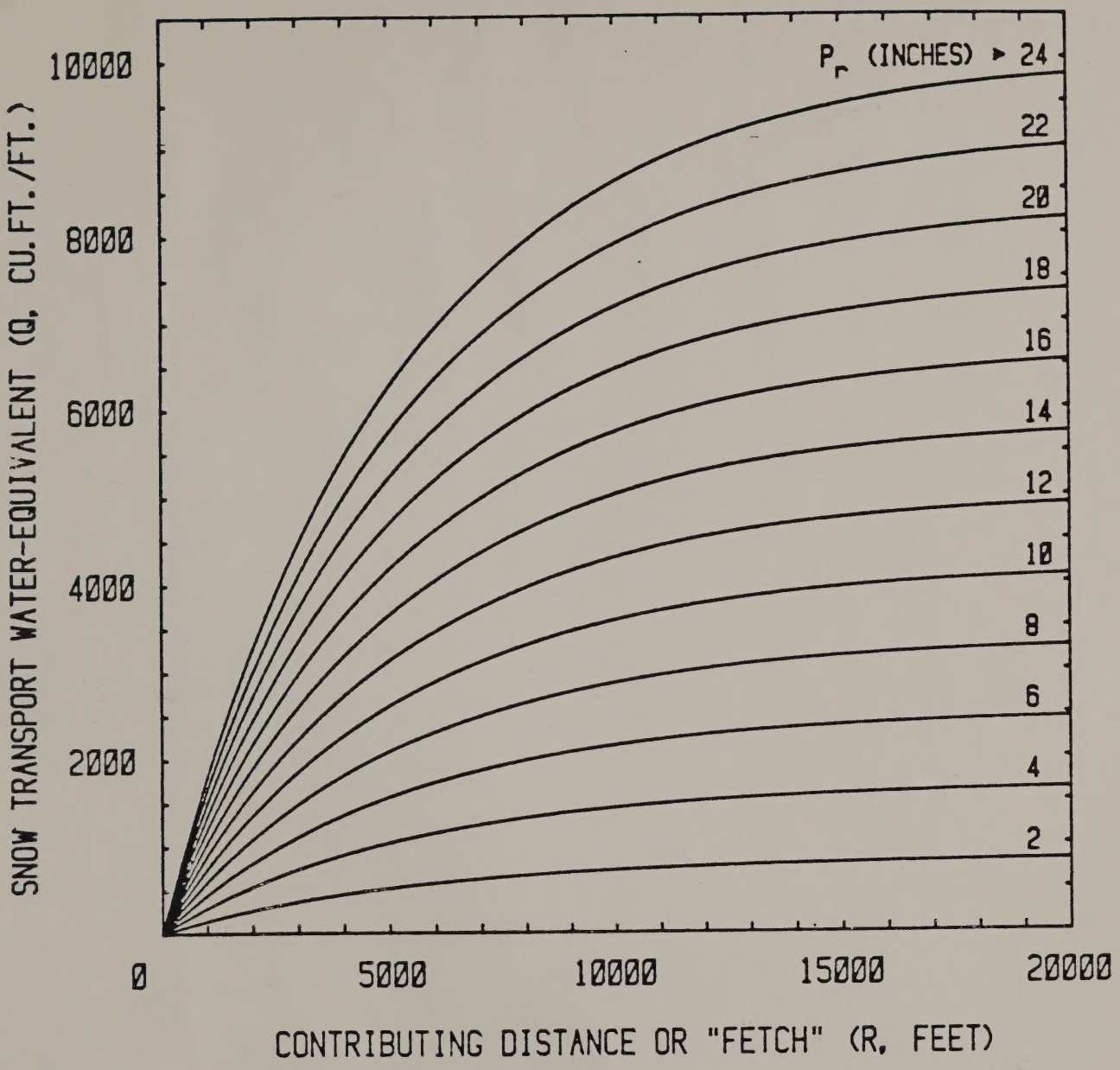


Figure 1. Curves for estimating snow transport from "fetch" distance and relocated precipitation. Graphical solution of

$$Q = 5000\ P_r\ \left(1 - (0.14)^{0.0001R} \right)$$

From Tabler, R.D. 1975. Estimating the transport and evaporation of blowing snow. Great Plains Agric. Council Publ. 73. pp. 85-104.

